. UNITED STATES OF AMERICA
AGENCY FOR INTERNATIONAL DEVELOPMENT

U. S. A. I. D. Mission to Kenya,
P. O. Box 30137,
Nairobi, Kenya.

June 20, 1966.

Mr. William W. Reedy
Division of Project Investigations
Bureau of Reclamation
Denver Federal Center
Denver, Colorado 80225

Dear Mr. Reedy:

I am happy to enclose two copies of the irrigation report made by the Russian group on the Kano Plain project.

I want to express to you our appreciation for the excellent work you did in bringing together the various factors involved in the considerations of this operation on the Kano Plain.

The Ministry of Agriculture is moving ahead rapidly with the other ministries with the development of the pilot project. We hope that the Department is planning to recruit a Planning Engineer with the qualifications that we discussed while you were here. Many of the people in the Ministry would be very happy to have you return for this assignment. I have not heard from Washington as to whether or not they will document this and allow us to have a man but I believe they will eventually get to it.

Kind regards to you and your wife.

Sincerely yours,

Elton

Elton M. Smith, Chief
Food and Agriculture Division

Enclosure:

TECHNICAL AND ECONOMIC CONSIDERATIONS ON IRRIGATION OF LANDS IN KANO PLAINS.

INTRODUCTION

In accordance with the Agreement on economic cooperation and technical assistance concluded between the Governments of the Soviet Union and the Republic of Kenya, the Soviet Union pledged to prepare the project report on irrigation of the Kano Plain in the Nyanza Province.

At the request of the Kenyan side before the preparation of the Project report there were determined the location and acreage of the irrigation area in the Kano Plain, found the ways of the most efficient use of the irrigation lands as well as mapped out the technical scheme of irrigation construction. This scheme should be the most optimum from the point of view of the future utilization of water resources in the basins of the Nyando, Ainomotua and Kibos rivers in the lower reaches of which the Kano Plain is located.

For this purpose, on the basis of the data given by the Kenyan side to the Soviet economic delegation (reports by Sir Alexander Gibb and Partners "Kenya Nile Basin Water Resources Survey", 1954-56 and "Extension of Kenya Nile Basin Water Resources Survey, 1960-61" and other data) there have been made preliminary engineering and economic calculations and designs which are shown in the present preliminary report (Technical and Economic Considerations).

The accuracy and reliability of the above calculations and designs as well as the recommendations correspond to the accuracy and reliability of the initial data. The available information on the natural and economic conditions in the Kano Plain cannot be regarded as complete enough. Therefore, it should be expected that as a result of the additional survey and research much of the engineering and economic data on the proposed measures will be changed. However, one may suppose, that future specifying will not greatly effect the results of the comparison and choice of the alternatives of the proposed measures.

In the Nyando and Ainomotua basins the lands suitable for irrigation cover 31 thous.ha (78,000 acres) nett including 19 thous.ha (48,000 acres) in the upper and middle reaches of the basin and 12, thous.ha (30,000 acres) in the lower part of the Kano Plain.

The present report considers the possibilities of irrigation of lands in the Kano Plain proper. The irrigation of lands in the upper and middle parts of the basin above the Kano Plain is rather well elucidated in the reports by Sir Alexander Gibb and Partners

The irrigation lands in the Kano Plain are proposed to be used under sugar cane plantations on the area of 5.9 thous.ha (14.6 thousand acres) and under rice on the area of 6 thous. ha (15 thous. acres). The main irrigation sources are the Nyando river with its tributary Ainomotua, the Kibos River, Lake Victoria and the Sondu river flowing south off the Kano Plain. The flow of the Nyando and Ainomotua rivers at the Ahero site equals 391 mill. cu.m (317 thous. acre-feet) in the mean water year and fluctuates by years from 126.1 mill. cu. m. (102.2 thous. acre-feet) to 619.3 mill. cu. m. (501.9 thous. acre-feet).

It is possible to irrigate 800 ha. (2,000 acres) from the Kibos river without flow regulation. This river has no permanent flow.

The mean many-year flow of the Sondu river amounts to 1064 mill. cu. m. (861,000 acre-feet). The water resources of Lake Victoria are practically unlimited.

For the irrigation of 19 thous.ha (48,000 acres) in the upper part of the basin 137 mill. cu. m (111 mi.. acre-feet of water are required; 250 mill. cu. m. (203,000 acre-feet) of water are required for the irrigation of the Kano Plain. Consequently, for the irrigation of the entire basin 387 mill. cu. m (314,000 acre-feet) of water are required.

The annual flow is distributed in such a way that its complete or partial utilization for irrigation is possible only under flow regulation by reservoirs. It is known that according to the topographic conditions it is possible to create five reservoirs in the basins of the Nyando and Ainomotua rivers. Their total storage capacity should not exceed 160 mill. cu. m. (130,000 acre-feet) the total cost being over 120 mill shillings.

The irrigation capacity of the non-regulated Nyando flow is 2, thous.ha (5,000 acres) under 75% probability and 1.5 th. ha. (3.5 th. acres) under 90% probability.

The preliminary design works have shown that the topographic and hydrologic conditions are favourable for the diversion of the non-regulated Sondu flow to the Kano Plain and thus to feed the insufficient Nyando flow. For this purpose it is necessary to construct a weir on the Sondu river and a tunnel connecting the Assawa river with the Nyando river. The tunnel is 600 m. (0.3 miles) long, its maximum discharge capacity being 20 cumecs (710 cusecs).

The total cost of these structures equals 39 mill. shillings. This is much cheaper than the regulation of the Nyando and Ainomotua flows.

Only 900 ha (2 th. acres) may be irrigated by the non-regulated 75% probability Sondu flow. About 660 ha. (1.6 th. acres) may be irrigated by the non-regulated 90% probability Sondu flow. When the Sondu and Nyando flows are utilized simultaneously (when the low-flow periods do not coincide) the irrigation capacity sharply increases. Hence it becomes possible to irrigate all the lands in the Kano Plain.

During 2-3 months water will be pumped from Lake Victoria to irrigate the area of about 3-4 th. ha. For this purpose drainage pumping stations may be used. These stations are proposed to divert flood water.

It is reasonable to irrigate the Kano Plain by the Sondu flow, provided the irrigation in the upper and middle parts of the basin is developed according to the proposed plan.

For this purpose a reservoir of annual regulation should be created on the Sondu river. This alternative is favourable for the solution of both the irrigation and power problems. In our opinion the reservoir construction will be needed in the far future.

Three pumping stations will be required to irrigate the lands in the Kano Plain. Their total installed capacity is 5.7 th. kw. the power consumed per year is 19.41 mill. kwh. This circumstance may necessitate the construction of a hydropower, or a thermal power station of the corresponding capacity, as the Republic of Kenya is short of free power and it is difficult to develop agriculture in this area with the use of the power imported from neighbouring Uganda.

Under the alternative of gravity irrigation by the non-regulated Nyando and Sondu flows the cost of construction and agricultural development of irrigation projects with necessary hydraulic, flood control and other structures amounts to 237.6 mill. shillings, the annual expenditure equalling 10.5 mill shillings.

Under the alternative of pump irrigation the construction cost has been calculated as 157 mill. shillings, the expenditures equalling 13.8 mill. sh. If the derivation hydropower station on the Sondu river is taken into account, the construction cost will be increased.

If the impossibility or inexpediency of the power import is proved, gravity irrigation with the use of the non-regulated Nyando and Sondu flows and additional irrigation by drainage pumping stations taking water from Lake Victoria should be recommended as the main development in the Kano Plain.

When comparing the alternatives of pump and gravity irrigation the account has not been taken of the creation of own power facilities for pump irrigation and of the regulating reservoir on the Sondu river. It should be noted that the creation of the reservoir on the Sondu river may be required only in the far future when the proposed irrigation lands covering 19 th. ha. (50 th. acres) in the upper and middle reaches of the Nyando river are completely developed. Practically, this reservoir is necessary to provide for the irrigation of only 4 th. ha. (10,000 acres) in the upper part of the basin. As the irrigation of the Kano Plain is considered as the first stage development it would be useful to reconsider the sizes of the irrigation areas in the upper and middle reaches of the Nyando river and give up the idea of the reservoir construction on the Sondu river which would cost not less than 200 mill. shillings.

The development of the Kano Plain is planned to be carried out by farmers having 2 ha. (5 acres) under sugar cane and 1.6 ha.(4 acres)under rice with their future consolidating into cooperatives served by machine-tractor stations. The organization of 2-3 state farms would be of benefit to the development of lands, agricultural production and irrigation.

The development of the irrigation lands within the proposed area and according to the recommended technical scheme will provide for 666 th. quintals gross of sugar cane production and 223 th. quintals gross, of rice production. The total annual cost of the agricultural produce is 43.1 mill. shillings.

The maintenance expenditures and agricultural production cost being not taken into account, the annual incremented income with due regard for the export prices on rice will be as follows: under gravity irrigation - 27 mill. shillings, under pump irrigation - 24 mill.shillings. The tentative net income per one farm is as follows: under gravity irrigation - 6600 shillings on the sugar land and 2900 shillings on rice land. Under pump irrigation 6000 shillings on sugar land amd 2500 shillings on rice land. The total capital invested in construction being 237 mill. shillings under gravity irrigation and 157 mill. shillings under pump irrigation, the delivery of Soviet machines, equipment and payment to the Soviet experts for rendering the technical assistance when designing, investigating constructing and developing the irrigation areas will be 95 mill. shillings and 63 mill. shillings correspondingly.

CHAPTER I - NATURAL CONDITIONS

1. Location and Topography

The Kano Plain covers the greater part of the Central Nyanza Province in the Republic of Kenya and is located between the latitudes of 0°5'N and 0°15' S.

The area under consideration is 400 km (250 miles) far from Nairobi, the capital of the Republic of Kenya.

The Kano Plain is a relatively flat area bordered on by Lake Victoria in the west and by a steep escarpment of the crystalline plateau in the north, east and south.

From the topographic point of view this area may be divided into three zones:

1. Firstly, there is the plain proper with land slopes of the order of 0.002, most of which lies between the lake shore, at an elevation of 3724.8 ft (1134 m) above sea level and the 3780 ft (1153 m) contour. This gently sloping area, broken in places by ridges and intersected by watercourses and rivers, covers about 150 sq. miles (38650 ha) including swamp land. Almost all the irrigable land on the Kano Plain is located within it.

2. To the east and north of the plain proper there is a belt of higher land with slopes of the order of 0.01. A small part of this area is suitable for irrigation, notably the southern Kibos area and the existing plantations of sugar cane.

3. The third zone is represented by the foothills of the escarpment where the land slopes are generally greater than 0.01 and the elevation is about 4000 ft (1200 m). According to the report by Sir Alexander Gibb and Partners there are no potential irrigation schemes in the zone.

The present technical and economic considerations show the possibilities of proper irrigation in the first zone (the lower part of the Kano Plain) with the exception of swamp land.

2. Climate

The climate of the area under consideration is sub-tropical, moderately hot and humid. The climate is considerably affected by the humid airstreams from the Congo basin. To give the climatic characteristics of the area the use has been made of the observation data of the Kisumu and Kibos meteorological stations.

Air temperature

The mean annual air temperature is 21.1°C. The air temperature information for the meteorological stations at Kisumu, Kibos is given in Tables 1 and 2. The given data show that the fluctuation of the mean monthly air temperature within a year is insignificant. The coolest months are July and August, the hottest months are February and March.

Table 1

Mean Annual, Mean Minimum, Mean Maximum Air Temperatures for Kisumu and Kibos Meteorological Stations.

(C°)

Stations	Elevation above MSL feet	Mean min.	Mean max.	Mean Annual
Kisumu	3769	17.2°	29.4°	23.3°
Kibos	3850	16.1°	29.4°	22.8°

Table 2

Mean Monthly, Maximum and Minimum Temperatures for Kisumu Meteorological Stations.

(C°)

Item	Jan	Feb	Mar	Apr	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Mean Monthly	23.9	24.5	24.7	23.7	22.7	22.2	21.8	21.7	23.1	24.1	23.9	23.3
Maximum	35.9	36.9	36.6	34.1	31.3	31.0	30.3	31.6	34.0	34.5	34.0	35.0
Minimum	13.8	13.8	14.6	15.6	15.5	12.7	13.0	13.5	12.4	13.1	14.2	14.4

Mean Monthly Per year 23.3
Maximum per year 36.9
Minimum per year 12.4

Rainfall

The total amount of annual rainfall in the Nyando basin varies from 1100 mm to 1500 mm. The rainfalls of about 1100 - 1300 mm occur in the Kano Plain. The maximum annual amount of rainfall over 1800 mm is observed over the Kericho Plateau in the Sondu basin. Mainly rainstorms occur, they are often accompanied by thunder. The maximum rainfall is observed in March-May when the amount of rainfall equals 500-600 mm. In the mountainous parts of the Nyando and Ainomotua basins and on the Kericho Plateau the wet season lasts longer, the maximum rainfalls being in April-May and August-September. About 900-1200 mm falls during this period. During the wet season the number of rainy days ranges from 10-17 in a month, during the rest of the time, from 4-8. Sometimes durative rainstorms occur, they last 5-6 days. The daily maximum amount of rainfall was observed during the period of 1956-61 at Kisumu and it reached 129 mm.

The monthly and annual rainfall of the area under consideration is given in Table 3.

The daily maximum amount of rainfall at Kisumu and the depth of the maximum flow of 5% and 10% probabilities in the Kano Plain are given below :

Table 4
(mm)

Item	5% probability	10% probability
Daily maximum rainfall	176	141
Depth of maximum flow	140	113

Wind - Table 5 shows mean wind velocities at Kisumu

Table 5
(m/sec)

Item	Jan	Feb	Mar	Apr	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Per year
0830	2.0	1.6	2.0	1.8	2.2	2.2	1.8	2.5	2.5	2.5	2.0	1.8	2.1
1430	6.7	7.2	6.9	5.4	4.5	4.2	4.2	4.5	5.8	5.8	4.9	5.2	5.5
Mean	4.4	4.4	4.4	3.6	3.4	3.2	3.0	3.5	4.2	4.2	3.4	3.5	3.8

According to the written information, the wind velocity seldom exceeds 11 m/sec south-western winds prevailing. The relative air humidity and daily sunshine hours for the observation period of 1931-62 at Kisumu are tabulated below:

Table 6

Item 1	Jan 2	Feb 3	Mar 4	Apr 5	May 6	June 7	July 8	Aug. 9	Sept 10	Oct. 11	Nov 12	Dec. 13	Per year 14
Mean daily sunshine hours.	7.7	8.1	7.8	7.3	7.2	6.7	6.0	6.1	7.0	7.2	6.5	7.6	7.1
Relative air humidity in % at 3 at night.	77	79	82	90	92	90	89	87	85	83	81	81	85
Relative air humidity in % at 12 in afternoon	41	40	44	53	56	53	50	50	47	42	44	45	47

Evaporation - The mean many-year evaporation from the water surface amounts to 2044 mm/year. The monthly evaporation is given below:

Table 7

Item	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Per year.
mm	175	172	187	160	156	147	150	164	175	220	176	162	2044

3. Hydrography

The given area is a part of the Nile basin in Kenya. The Nzoia, Yala, Kibos, Nyando, Sondu, Kyia and Mara flow into Lake Victoria. The rivers are listed from north to south. On the Kano Plain there are found the middle and lower parts of the catchment areas of the Kibos, Nyando, Ainomotua rivers, as well as the catchment areas of several smaller streams originating at the Nandi escarpment and flowing in the inter-river area of Kibos-Nyando.

Nor far from the southern watershed of the Kano Plain the Sondu river flows

The hydrology of the main rivers and Lake Victoria is considered below:

The Nyando river rises in the Tinderet forest near Londiani at an elevation of 9000 ft (2743 m) and flows from the east to the west, below Ahero it flows to the south and enters the Miruka swamp. The swamp spills its water into Nyakach Bay of Lake Victoria. The catchment area is 1050 sq. miles (1690 sq km). The main tributaries of the Nyando river are the Ainomotua, the Namuting and the Mbogo. In their upper reaches these tributaries are rapid but they do not overflow the banks. There are many small dams on the tributaries in the upper part of the Nyando basin which store much of the initial flow. That is why the Nyando flow is rather low as compared to the rivers of the neighbouring basins. During the seasonal rains about two miles to the north of Ahero the Nyando river overflows the banks and inundates big areas.

The Ainomotua river the main tributary of the Nyando river rises in the Tinderet forest near Timboroa. In the upper reaches it flows through steep hilly country and then flattens out. Two miles below Kibigori it joins the Nyando river. The catchment area is 530 sq. miles (1373 sq km)

The Sondu river rises in the high elevated bamboo forests of the western Mau forest and flows westward through the Kericho tea estates. Then it runs through the Nyakach peninsula and flows into the Kavirondo gulf of Lake Victoria. The catchment area is 1269 sq. miles (3289 sq. km). A considerable amount of rainfall (above 1800 mm) occurs in the upper part of the Sondu catchment area. Therefore the Sondu flow is higher than the flows of other rivers. The river gradient in the upper reaches is 0.0265.

Lake Victoria is located in Kenya between the latitudes of $0^{\circ}30'N$ and $3^{\circ}S$ within the boundaries of Kenya, Uganda and Tanzania. The water surface area is 26 th. sq. miles (68,000 sq. km). The lake has many islands. The length of the highly broken shore line exceeds 7,000 km. Numerous rivers flow into the lake, the total area of their basins approximates 80,000 sq. miles (200,000 sq. km). The average depth of the lake is about 40m; the maximum depth being 80 m. The total mean annual amount of water flowing into the Lake (the river flow and the rainfall) equals 81 mill. acre-feet (100 cu. km.) The volume of water evaporated is about 74 mill. acre-feet (92 cu. km).

The water layer annually evaporated is 1350 mm. The flow from the lake amounts to about 15 mill. acre feet (18 cu. km). The seasonal water level fluctuation in the lake is 2 ft (65 cm), the many-year fluctuation being 5 ft (1.5m), the maximum fluctuation 6 ft (1.8 m).

4. Geologic Structure and Hydrogeologic Conditions

The Kano Plain covers some part of the rift valley of the Kavirondo Gulf (Lake Victoria) formed in the early Pleistocene period. From the point of view of the geology the Kano Plain and the adjacent areas are composed of intrusion, effusion and sedimentary deposits of the pre-Cambrian period as well as of Tertiary and loose recent sediments. The recent sediments are well developed over the plain and are represented with different genetic complexes. At the foothills, erosional slopes and escarpments deluvial deposits occur. They are represented with rock drift of different sizes. Their thickness is 100 ft (30 m).

Along the channels of numerous rivers as well as in their swampy deltas alluvial deposits occur. From the point of view of the lithology they are represented with silty loam and heavy clay characterized with high content of clayey particles (up to 80%). Infiltration properties of alluvial deposits are very low, infiltration rate is not over 0.15 m/day).

Laterites are widely spread over the described territory. They are the product of destruction of volcanic rocks under the conditions of hot humid climate. Laterites are met on all types of rocks and their thickness is from several inches to 15 ft (4.6 m). The ground water is confined to lacustrine and alluvial deposits.

We know only the general information pertaining to the depth of ground water occurrence, chemical composition of ground water and its general mineralization. South of the Kisumu-Nairobi road ground water occurs almost at the elevations of the Lake, i.e. 3724.8 ft (1134 m) The depth of ground water occurrence within this area changes from 3.28 to 32.81 ft. Closer to the lake and the Nyando river the ground water table smoothly rises reaching 5-12 feet (1.5-3.7 m) from the ground surface. Moving from the lake and the river the ground water occurrence becomes deeper and at Rabour it is as deep as 18 ft (5.5 m).

North of the Kisumu-Nairobi road the ground water table is 30 ft above the water line of the lake reaching 3750 feet (1143 m). The depth of ground water occurrence changes from 35 feet (10.7 m) to 50 feet (15.2 m).

The shore of the Kavirondo gulf is swampy almost along its entire length. Many swamps are met in the river valleys and deltas. Large swamps occur in the south-western part of the valley (the Miruka swamp).

Ground water as well as water of the surface streams has very low mineralization and is classified as sweet water. The content of dry residue in the river water does not exceed 0,1 g/l. Ground water mineralization is somewhat higher but much less than 1 g/l. Only at two points, i.e. near Nduru (Borehole 12) and Nyamware (borehole 3), mineralization of the ground water occurring at the depth of about 5 m. is high. This probably due to the stagnant regime of ground water near the shore of the gulf. Water is probably hydrocarbonaceous, containing much sodium.

The ground water is mainly recharged due to the underground water inflow from the surrounding mountains, due to the infiltration of the rainfall, as well as due to the surface water infiltration during floods. The water is relieved on its way to the lake while its main portion is lost on evaporation and transpired by plants. Irrigation of the lands in the Kano Plain will cause the increase of the ground water recharge due to infiltration thus increasing the inflow portion of the ground water balance. Under the conditions of difficult natural outflow, because of poor infiltration properties of the soils and back-up from the lake this may result in the rise of ground water on the lands where the ground water table is relatively deep (10-20 feet or 3-6 m) as well as in the extension of swampy areas where the ground water table is shallow.

According to the soil information available the soils are not saline, they do not require periodic leachings, the ground water is practically sweet. Therefore there is no necessity in the drainage construction.

Under these conditions over the greater part of the area provision should be made for the construction of the collecting-drainage network to timely remove the rain and drainage water and for flood control measures aimed at the reduction to the minimum the inflow of flood and rain water coming down from the areas located at higher elevations.

5. Soil Reclamation Conditions

Taking into account the previous investigations carried out in the Plain there were distinguished five soil groups.

Group 1 - dark clays and clay loams underlain by clay are referred to Vertisol according to the classification of the 7th Approximation. This soil type is one of those mostly spread in the Kano Plain. The soils of this group occupy 52,000 acres (21 th. ha)they were formed on the recent alluvial deposits under the conditions of temporary flooding.

Dark clays and dark clay loams are fertile. It may be stated that these soils suffer from the deficiency of nitrogen as compared with the soils of other parts of East Africa. The majority of these soils are being intensively used for the cultivation of sorghum, maize, rice, legumes, etc. The soils of this group are not saline as a rule ($EC1 \times 10^3$ less than 4). They are alkaline in certain areas.

When dry these soils are fissured and are of blocky structure. When wet they float. In the main poor aeration and low permeability are characteristic of these soils that is why the internal drainage is also poor. The construction of a drainage network is a must. This network would improve water-and-air soil regime. As the nutrients are insufficient in the soil it is necessary to apply organic and mineral fertilizers. Alkali kinds of dark clays require gypsum and application. The rates of gypsum application should be verified in the process of further investigations.

Low permeability will permit to use the method of surface irrigation through long furrows and strips. Deep furrows with wide inter-furrow spacing are required to improve the water-and-air regime when cultivating sugar cane.

Group 2 - dark clays of seasonal and permanent swamps. The soils of this group in the described area cover 6260 ha. of the swampy plain. The soils of seasonal and permanent swamps are much alike by their physical and chemical properties. These soils are under constant over-wetting and this determines their properties. Because of their fine texture they are difficult to work. The soils are alkaline in certain areas having poor structure. The soils are poorly aerated and very slowly permeable to water.

After cultural operations these soils can be used for the growing of rice, sugar cane, maize, sorghum, legumes etc. When using the soils of seasonal and permanent swamps in irrigation farming the soils of this group would require the same cultural operations as those of group 1.

Group 3- Sandy loams and loamy sands of Lake beaches. They cover the area of about 1060 acres (430 ha). The soils of this group occur as small patches along the shore of the lake. Usually these soils are gravelly or sandy in texture, highly saline. Infiltration rates are high, the fertility of these soils is low. They require serious cultural operations for their desalinization. The cultural developments include: the construction of cut-off collectors along the shore of the lake, the construction of a drainage network and leaching of these lands before their use. Because of the coarse soil texture, leachings and water applications should be carried out through short furrows and strips. In future the application of considerable amounts of organic and mineral fertilizers will be required. When using these soils low irrigation rates are recommended. The agricultural use of these soils is not reasonable.

Group 4 - Silty clay and sandy clay loam soils on river levees. Within the entire Kano Plain small remnants are scattered near the rivers, small remnants are composed of ferruginated sandstone. Probably, they are the remnants of the ancient alluvial surface. The area makes up 1380 ha. The lack of the vegetation of these soils is the result of highly compact surface of these soils. The soils are low permeability and are often highly saline. These soils are not suitable for agriculture.

Group 5 - Colluvial-Alluvial Soil Complex is met along the foot slopes of the hilly terrain and cover the area of 5000 ha. They are of coarse and medium texture (loamy sand, sandy loam, loam). The soils are not quite suited to irrigation farming because the areas are often dissected by erosion gullies.

CHAPTER II - PRESENT & FUTURE USE OF LANDS IN KANO PLAIN

1. Short description of Present Use of Lands

The Kano Plain is located in the eastern part of the Central region of the Nyanza Province. The area totals 2530 sq. miles (6564 sq. km) of this figure 148 sq. miles (385 sq. km) are in the Kano Plain.

The population of the Kano Plain approximates 715.5 thousand persons. The labour available can be used when carrying out projects of agricultural development.

According to the Agricultural Census of 1960-61, the cultivated area in the Central Nyanza Province is as follows: during the period of long rains 216,8 th. ha (535.7 th. acres) during the period of short rains - 19.6 th. ha. (48.4 th acres). Besides 1.6 th. ha. (4.0 th. acres) are under perennial crops. According to the latest data the area under perennial crops is as large as 4.8 th. ha (11.9 th. acres). The percentage of the agricultural lands in the Central Nyanza Province is represented below. The data is based on the agricultural census of 1960-61.

Table 8

Item	Ploughland incl: Total	Field crops	Fallow	Perennial Plantings	Pas-tures	Forest	Brush	Other
Agric. lands in the regions investigated								
Thous. ha	134.8	125.2	9.6	0.9	168.2	3.2	0.2	7.6
Thous. acres	333.1	309.4	23.7	2.2	415.6	7.9	0.5	18.8
Agricultural lands, %age	42.8	39.8	3.0	0.3	53.4	1.0	0.1	2.4

The tentative distribution of the ploughland under crops in the Kano Plain is shown in Table 9:

Table 9

Crops	Period of long rains Area ha.	acres.	%	Period of short rains Area ha.	Acres.	%
Rice	242	483	0.9	-	-	-
Cotton	2800	7000	10.8	-	-	-
Sugar cane	520	1300	2.0	-	-	-
Maize	4400	11000	17.2	2800	7000	94.6
Sorghum	14800	37000	57.7	-	-	-
Vegetables	280	700	1.1	40	100	1.4
Manioc	320	800	1.2	-	-	-
Potato	1200	3000	4.7	-	-	-
Legumes	200	5000	0.8	-	-	-
Coffee	12	30	0.1	-	-	-
Groundnuts	400	1000	1.6	-	-	-
Banana	280	700	1.1	-	-	-
Sisal	80	200	0.3	-	-	-
Other	120	300	0.5	120	300	4.0
Total	25654	68513	100.0	1960	7400	100.0

Animal husbandry in the Central Nyanza Province is regarded rather as a sign of richness than the branch that can produce profit. The cattle is low productive, of local breeds.

2. Proposed Use of Reclaimed Lands

The present considerations plan to irrigate the lands in the Kano Plain on the area of 12 th. ha. net (29.6 th acres). Improvement developments should result in considerable increase of the profitableness of the lands under consideration. Therefore on the lands to be improved in the Kano Plain crops should be chosen so as to suit the climatic conditions, to be well supplied with water.

It is evident from the materials submitted by the Kenyan side that cultivation of the irrigated sugar cane, rice and cotton is planned in the Kano Plain. From the wide range of crops that could be grown on the irrigated land, rice and sugar cane are most promising.

The work "National Cash Crop Policy" characterizes these regions as the most climatically favourable for the cultivation of sugar cane in Kenya. At present sugar production is concentrated in the Nyanza and Coastal Provinces. Sugar cane is one of the most important items of the Kenyan import. Almost one-third of sugar requirements in the country is met by the import. The ever-growing demands in sugar require considerable increase of sugar production. The development plan of agriculture in Kenya envisages the extension of sugar lands including the Kano Plain and the construction of new sugar refineries. The liquidation of sugar import will result in the increase of a farmer's annual income by £1 million.

In 1963 the rice consumption reached about 110 th. quintals while its production equalled 90 th. quintals. At present the policy of Kenya in rice production is aimed at the elimination of import and the increase of rice production meant for export.

The soils of the Kano Plain are well suited to rice cultivation. They are mainly represented by clay or fat loam with high content of clay and silt, poorly drained. The problem of the efficiency of cotton cultivation as the major crop can be solved if additional investigations are carried out Thus the major crops recommended by the present considerations for cultivation on the irrigation lands are sugar cane and rice.

It is proposed to use the reclaimed lands in the following way:

Table 10

Area		Total	Incl. plantations under: Rice	Sugar Cane
Gross	(ha	15380	7790	7590
	(acres	38000	19250	18750
Net	(ha	12000	6080	5920
	(acres	29650	15020	14630

The areas under separate crops are as follows:

Table 11

Item		Total	Including: Sugar Cane	Rice	Legumes	Sorghum	Maize	Crops chosen by farmers
1		2	3	4	5	6	7	8
				Cane production				
Area	(ha	5920	5330	-	-	-	-	590
	(acres	14630	13170	-	-	-	-	1460
	%	100	90	-	-	-	-	10
				Rice field				
Major crops								
Area	(ha	6080	-	4560	-	-	-	1520
	(acres	15020	-	11270	-	-	-	3750
	%	100	-	75	-	-	-	25
Succession crops								
Area	(ha	6080*	-	-	1520	760	760	1520
	(acres	15020	-	-	3760	1870	1870	3760
	%	100*	-	-	25	12.5	12.5	25

*Including fallow land of 1520 ha (3760 acres) this makes 25%

It is evident from the Table that 10% of sugar lands and 25% of rice lands are chosen by a farmer.

Greater annual income may be attained if cash crops are grown on the entire area of each holding. But taking into consideration the traditions of the local population it is posposed to grow food crops on some portion of the holding. Sugar cane plantations are used for 5.5 years. Four harvests are planned to be yielded. Then after the last yield green manure crops are sown which are then ploughed-in prior to the organization of a new plantation.

The following crop rotation is proposed on the rice lands.

First season	- Rice	100%
Second season	- Legumes	33.3%
	Sorghum	16.7%
	Maize	16.7%
	Fallow	33.3%

Several planting dates for sugar cane and rice are planned in order to assure an even labour distribution and an even supply of the produce to factories. According to the information submitted by the Kenyan side the yielding capacity of sugar cane in the Kano Plain ranges from 50 - 175 tons per ha (2000 - 7000 quintals per acre) at present. The average yield obtained from the area of 520 ha (1300 acres) has been estimated to be 125 tons per ha (5000 quintals per acre). The yielding capacity of sugar cane grown on non-irrigated plantations in Miwani averages 75 tons per ha (3000 quintals per acre) and varies from 50 - 100 tons per ha (2000 - 4000 quintals per acre). When testing sugar cane varieties on small plots the results obtained were as follows:

Table 12

(3 crops on the average)

Item	Varieties				
	B41227	C0331	C0419	NC0310	C0421
Without irrigation, t/ha	99.4	128.3	89.6	101.2	89.4
th.quintals/acre	4.0	5.2	3.6	4.1	3.6
Under irrigation, t/ha	276.4	165.6	160.4	160.1	148.3
th/quintals/acre	7.1	6.7	6.5	6.5	6.0

It may be supposed that under the field conditions the yielding capacity of irrigated sugar cane will be about 125 tons per ha (5000 quintals per acre) i.e. the increment due to irrigation being 50 tons per ha (2000 quintals per acre).

The yielding capacity of paddy rice in the country was estimated to be 28.8 quintals/ha (11.6 quintals/acre) in 1963-64. On the Mwea irrigation system the yield obtained in 1962 from the area of 2 thousand ha. (5000 acres) was about 60 quintals per ha. (24 quintals per acre). On some areas the yield of raw rice was 91.2 quintals per ha. (37 quintals per acre) per two croppings. The yielding capacity of rice in the Kano Plain averages 50 quintals per ha (20 quintals per acre) ranging from 22 to 70 quintals per ha (9-30 quintals per acre).

The yielding capacities of the main food crops in the Kano Plain are as follows:

Maize - 13.5 quintals per ha. (6 quintals per acre) ranging from 9-27 quintals per ha. (3.6-11 quintals per acre)

Sorghum: 18 quintals per ha (7 quintals per acre) ranging from 9-34 quintals per ha (3.6 - 14 quintals per acre)

Legumes: 11 quintals per ha (4.4 quintals per acre) ranging from 6-22 quintals per ha (2.4 - 9 quintals per acre).

In 1963-64 average yields obtained in the Nyanza Province were as follows:

Maize - 24 quintals per ha. (9.7 quintals per acre)
Legumes - 8 quintals per ha. (3.2 quintals per acre)
Sorghum - 12.6 quintals per ha (5.1 quintals per acre).

Viewing the above-mentioned, the yields of sugar cane and rice are rather high at present. Taking into account higher level of farming practices (thorough soil preparation, application of fertilizers etc) the following design yields have been adopted:

Sugar cane - 1250 quintals per ha (500 quintals per acre)
Rice - 50 quintals per ha (20 quintals per acre)
Legumes - 11 quintals per ha (4 quintals per acre)
Sorghum - 18 quintals per ha (7 quintals per acre)
Maize - 27 quintals per ha (11 quintals per acre)

The proposed gross yield from the entire irrigation area and its cost are given below:

Table 13

Crop	Gross yield th.quintals	Cost of quintal	Cost of gross yield, th.Sh
1	2	3	4
	Sugar cane plantations:		
Sugar cane	6661.3	4.5	29981.3
Crops chosen by a farmer	-	-	592.0
Total			30573.3
	Rice fields		
Paddy rice	227.9	40	9116.0
Legumes	16.7	50	835.0
Sorghum	13.7	24	328.8
Maize	20.5	35	717.5
Crops chosen by a farmer*			1520.0
Total			12517.3
Grand total			43090.6

*The cost of produce of crops chosen by a farmer has been determined as Sh1000 per ha. (Sh405 per acre).

The cost of gross agricultural produce has been calculated by the prices adopted in the report by Sir Alexander Gibb and Partners: "Extension of Kenya Nile Basin Water Resources Survey, 1960-61" These costs can be ensured after the marketing of the agricultural produce.

It is supposed that the development of the improved lands will be carried out by farmers. One of the main tasks, the Kenya agriculture is confronted with at present, is to improve the subsistence minimum for a farmer and to obtain annually about £100 of the income.

The optimum size of holdings has been determined with regard to their tillage by a family (6 persons, including 3 adults) and with regard for the proposed net income. The size of the holding on sugar cane plantations is 2 ha. (5 acres) of which 1.8 ha (4.5 acres) are to be under sugar cane and 0.2 ha (0.5 acre) is to be under food and other crops according to the choice of a landholder. The size of the holding in rice growing farms is 1.6 ha (4 acres) including 1.2 ha (3 acres) under rice and 0.4 ha (1 acre) under food and other crops according to the choice of a landholder.

The gross produce and its cost per one holding are given below:

Table 14

Crop	Area - ha	acre	Yield quintals - per ha.	per acre	Total yield, quintals	Cost of total yield, Sh
			Sugar cane plantations			
Sugar cane	1.8	4.5	1250	505	2250	10125.0
Crops chosen by a farmer	0.2	0.5				200.0
Total	2.0	5.0				10325.0
			Rice fields			
Rice, paddy	1.2	3.0	50	20	60	2400
Legumes	0.4	1.0	11	4	4.4	2200
Sorghum	0.2	0.5	18	7	3.6	86.0
Maize	0.2	0.5	27	11	5.4	189.0
Crops chosen by farmer	0.4	1.0				400.0
Total	2.4	5.0				5275

The development of the Kano Plain is planned to be commenced with the establishment of an experimental pilot farm on the area of 200 ha (500 acre). This farm should train farmers in proper running of irrigation agriculture. About 100 families will receive holdings in this farm. The number of holdings on the lands to be improved, except the experimental pilot farm, will total: on sugar cane plantations 2910, in rice fields 3736.

The Development Plan states that much of the agricultural development depends on a continuing program of consolidating fragmented land holdings. Modern methods of farming cannot be applied to small farms. However, once a holding has been consolidated into a compact unit, it becomes possible to apply modern methods of farming. At present cooperatives have been organized to market holders' produce and to perform the mechanical operations.

Viewing the above land holdings may be consolidated into cooperatives, the organization of state farms is possible.

3. Agricultural Developments

The tentative expenditures on agricultural development will approximate 11090.0 th. Sh. The following measures on the agricultural development of the reclaimed lands are considered in the present chapter.

(1) Land organization is necessary in connection with the construction of the irrigation and drainage networks as well as the distribution of holdings among farmers. The tentative cost of these works being Sh12 per ha, the expenditures meant for land organization will total Sh184,000, including Sh90,000 invested in sugar plantations and Sh94,000 in rice growing farms.

(2) About 1000 ha of the lands to be reclaimed are under brush. The cost of thin brush clearing is Sh250 per ha. The total expenditure on brush clearing has been estimated as Sh250,000.

(3) The cost of improved earth roads has been accepted similarly to the report by Sir Alexander Gibb and Partners "Extension of Kenya Nile Basin Water Resources Survey, 1960-61" making Sh 6,943,000

(4) As it has been already mentioned the development of the Kano Plains is planned to be commenced with the establishment of the experimental pilot farm 200 ha. in size. The expenditure required for its establishment (purchasing of equipment, construction of administrative facilities, workshops, storehouses etc) will approximate 1300.0 th. sh.

(5) The introduction of advanced methods of farming requires the organization of training of farmers. To train farmers in running of irrigation agriculture it is proposed to establish a training center costing Sh300,000. The cost of training one farmer is about Sh40. Thus, the expenditures required for the training of farmers are estimated to be 165.8 th. Sh, including 116.4 th.Sh on sugar plantations and 149.4 th.Sh on rice growing farms.

(6) About 6750 families will be necessary for the development of the area to be reclaimed. There will be no labour problem when developing this area. This means that no additional expenditures connected with the shifting of the population are required.

(7) The advantages of the mechanized cultivation of the area are evident. The program of the agricultural development in the Nyanza Province for 1964-70 envisages the establishment of six machine-tractor stations. One station is proposed at Ahero, it will serve the lands of the Kano Plain. The land holders are allowed to use machines of the station on their lands paying certain sum for the use. Viewing the above the present work does not treat the problem of machine import.

Given below is the table showing expenditures meant for the agricultural development:

Table 15

Proposed measures	Expenditures - Sh 000		
	Total	Sugar cane plantations	Rice fields
1.Land organization	184.0	90.0	94.0
2.Bush clearing	250.0	123.4	126.6
3.Road construction	6942.6	3426.2	3516.4
4.Establishment of experimental pilot farm	1300.0	641.5	659.4
5.Establishment of training center	300.0	148.1	152.0
6.Training of farmers	265.8	131.2	134.6
7.Unforeseen expenditures making 20% of the total sum	1848.5	912.1	936.4
Total	11090.9	5472.5	5618.4
Net Sh per ha.	924	924	924
Net Sh per acre	374	374	374

CHAPTER III - AREA UNDER PROPOSED IRRIGATION

In accordance with "Kenya Nile Basin Water Resources Survey, 1954-56 and Extension of Kenya Nile Basin Water Resources Survey, 1960-61 about 34860 ha of land may be irrigated in the Kano Plain.

These lands are distributed between two main zones:

1. The middle and upper parts of the Nyando and Ainomotua catchment areas and sugar cane plantations below the Nandi escarpment. They are located:

In the upper reaches of the Nyando river:

	ha	acres
In Koru area	6925	17150
Upstream Koru	300	740
At Awasi	2612	6430
Total	9837	24320

In the basin of the Ainomotua river:

	ha	acres
On the Mtetei river	3684	9110
At Twin bridges	5937	14700
Total	9641	23810
Grand total	19478	48130

2. The Kano Plain proper, its lower deltaic part below Ahero with the total area of 15380 ha. The engineering developments pertaining to the irrigation of the first zone, i.e. the middle and upper parts of the Nyando and Ainomotua catchment areas are considered in details in "Extension of Kenya Nile Basin Water Resources Survey" prepared in 1960-61.

The present technical and Economic considerations deal with the problem of irrigation of the second zone, i.e. the lower part of the Kano Plain. The size of the area proposed for irrigation has been determined on the basis of the data of the soil survey carried out by Sir Alexander Gibb and Partners. The land use factor has been adopted as 0.78. The distribution of the land resources is given below:

Table 16

Lands	Gross area.	Areas excluded from irrigation: Acc to soil conditions:	Areas excluded from irrigation: Other acquisition areas (acc.to topography, settlement, etc)	Irrigation areas: Gross	Land use factor	Net
Lower part of Kano Plain:						
Ha	38650	10760	12510	15380		12000
Acres	95500	26600	30900	38000	0.78	29650
						including:
			Sugar lands:	ha		5922
				Acres		14630
			Rice lands:	ha		6078
				Acres		15020
Kibos river basin: Ha				1040		810
Acres				2570	0.78	2010

There are no data on the lands suitable for irrigation in the Sondu river basin. Taking into consideration the fact that the Sondu river runs in hilly regions, the size of the lands suitable for irrigation is expected to be small.

CHAPTER IV - IRRIGATION OF CROPS

The climatic and soil conditions of the Kano Plain are favourable for growing any crop. However, high and reliable yields are impossible because of the insufficient rainfall and droughts. The present chapter is based on the data and recommendations of projects, reports, papers of agricultural experts which are written for Kenya and other African countries with similar natural conditions.

The water consumption of the adopted irrigation crops have been determined by Blaney-Criddle's method. This method is widely used in water studies. The method is based on the relation between the water consumption and the mean monthly air temperature, monthly duration of sunshine hours and crop coefficient.

$$E = \frac{tp}{100} K$$

where:

E - water consumption (inches)
t - mean monthly air temperature, °F
p - monthly duration of sunshine hours
% of the annual figure
K - crop factor, the experimental crop factor has been adopted by the analogy with the irrigation projects in Tanzania and Ghana.

The initial data and the results of the computation of the water consumption and irrigation requirements are given in Table 17. The irrigation requirements for each crop have been calculated with due regard for its water consumption, effective rainfall, methods of water application, duration of the vegetation and irrigation periods. In order to estimate the effective rainfall 50% of the mean monthly rainfall at Ahero have been adopted. This value of the effective rainfall (552 mm) is close to the values adopted in the report by Sir Alexander Gibb & Co (539-645 mm).

The surface gravity method of water application has been proposed, sugar cane and "free" crops being irrigated through furrows, rice and succession crops to be sown after rice on the same fields being irrigated through well-levelled checks. The coefficient that takes into account conveyance and escape losses in the fields during the period of water application to sugar cane, "free"crops and succession crops has been adopted as equalling 1.3. The losses in the rice field have been taken into consideration when determining the irrigation requirements of rice by the method of water balance in the rice field. This method is given below.

The time of sowing, cropping and the duration of the vegetation period of irrigation crops have been adopted on the basis of the local experience. The experience in sugar cane growing gained in Kenya and in the neighbouring African countries has proved that the planting and harvesting (cutting) of sugar cane are possible throughout a year with the exception of the rainy seasons. Sugar caneis planted every 4-5 years depending on the number of harvestings. The first harvesting begins 16-18 months after planting while further harvestings after 12-14 months from the beginning of growth. During the dry season sugar cane is irrigated with the interval of 12 - 14 days. The water application is stopped six weeks prior to harvesting.

The scheme of sugar cane cultivation shown in table 18 has been adopted for the calculations. In order to assure an even supply of cane to factories, planting and harvesting would need to be spread over three periods with an interval of three months. The most intense year of the four-year period of cane cultivation has been adopted as a design one. This is the year when sugar cane is irrigated every month. The design planting, harvesting and watering dates of rice, succession and "free" crops in rice growing farms are given in table 19. The irrigation requirements have been determined by the formula of water balance of a rice field:

$$M_0 = W_1+W_2+W_3+W_4+W_5$$

in which M_0 = irrigation requirements, mm

W_1 = volume of water required for the saturation of the soil layer up to full moisture capacity. In the given case W_1=140 mm, the mean depth of ground water prior to saturation being 1 m, the soil porosity being 48%, the field moisture capacity of 1 m soil layer being 450 m, drying up of soil before saturation making 75% of the field moisture capacity.

W_2 = volume of water required for creation in checks of water layer upto 15 cm thick, W_2=150 mm.

W_3 = water consumption determined by Blaney-Criddle's formula minus 50% of rainfall, W_3 = 630 mm.

W_4 = seepage losses through peripheral bunds and drainage runoff. $0.3W_4$=200 mm.

W_5 = Conveyance losses, $0.2 (W_3+ W_4)$ = 170 mm

The design irrigation requirements of rice will be:

M_0 = 140+150+630+200+170 = 1290 mm

Table 20

Average irrigation requirements and design Water Duties for Cane and Rice growing Farms

Item	Months												Annual	Seasonal
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec		
S	Irrigation requirements for Cane Growing farms													
Sugar cane, 90%	179	161	129	105	105	149	156	141	163	169	157	165	1779	
"Free" crops, 10%	11	10	6	3	3	9	9	8	10	10	9	10	98	
Total mm	190	171	135	108	108	158	165	149	173	179	166	175	1877	
Design water duty 1/sec/ha	0.70	0.70	0.50	0.40	0.40	0.60	0.60	0.56	0.67	0.68	0.64	0.65		
	Irrigation requirements of rice growing farms													
Rice, 75%		105	150	180	67	134	162	167						965
Succession crops, 75%									75	78	71	74		298
"Free" crops, 25%	30	25	15	4	4	9	22	24	19	25	26	24	25	252
Total, mm	30	130	165	184	71	143	184	191	19	100	104	95	99	515
Design water duty, 1/sec/ha	0.10	0.54	0.64	1.45	0.54	0.55	0.71	0.71	0.07	0.38	0.39	0.37	0.37	

Table 20 shows average irrigation requirements and design water duties for cane and rice growing farms. The average irrigation requirements for rice and cane growing farms given in Table 20 are somewhat higher (1100 - 1150 mm) than the average irrigation requirements adopted in the report of Sir Alexander Gibb and Partners

CHAPTER V - IRRIGATION SOURCES

The main irrigation sources in the Kano Plain are Lake Victoria and the Nyando river together with its main tributary, the Ainomotua river. Other rivers and streams of the Kano Plain the largest being the Kibos, Ngaita, Great and Little Oruba are characterized by an insignificant flow during the low-water period and thus cannot be regarded as reliable irrigation sources. For the irrigation of the Plain the use can be made of the Sondu flow. This river runs not far from the south watershed of the Kano Plain.

Gauging and Meteorological Stations

The observations over the river flows are being carried out by the Kenyan Hydrometric Service. In the Nyando basin the flows are recorded at 18 gauging stations, 11 stations are in use less than five years and 7 stations function for five years and more. The long observation row beginning from May 1948 is available for the Nyando river at Ahero.

On the Sondu river there is only one station at the village of Sondu. It was established in 1947.

Incomplete observation data are available for four stations on the Nyando river, two stations on the Ainomotua river and a station on the Sondu river. The data pertaining to the above stations are given in table 21, the layout is represented in Map 1 (sheet No. 1)

No zeroes of the graphs at the stations and cross-sections of the station sites are available. That is why it seems impossible to connect water levels to the locality. The observations over maximum water levels and discharges are not available.

Rate of Flow

The rate of flow in the Nyando basin has been defined for the site at Ahero. This site has been accepted as the main one, as the observations were carried out during 13 complete years. The 13-year observation period (1948-1960) was made as long as 33-year period (1931-64). For the period from 1931 -47 the annual flow has been accepted in relation to the rainfall. During the recent four years from 1961 to 1964 the Nyando flow was obtained by the analogy with the Ainomotua flow at 1GB5. Mean annual many-year flow of the Nyando river at Ahero is 317 th. acre-feet or 391 mill. cu. m.

As for the Sondu river the observation data over flows for the complete 16 years (1947-64) are available for 1JG1. During this period the mean annual flow of the Sondu river is 1107 mill cu m (897 th. acre- feet), the coefficient of variation being 0.47. It was not possible to prolong the observation period (which would be useful for defining the flow rate) because of the lack of correlation with the rivers of the Nyando river basin. To recover the flow by the relation with the rainfall was not possible because of the lack of the data on rainfall within a number of years. Therefore the flow rate has been accepted in conformity with "Kenya Nile Basin Resources Survey, 1954-56." The annual flow rate is 861 th. acre feet or 1064 mill. cu m.

As for the design sites the flow has been calculated either by the correlation graphs of the Nyando river at Ahero or (when the observations over the flow were not made) by the modulus of the annual flow at the nearest gauging station on the Nyando river.

Mean many-year flow for a number of years and the flow for the period from 1931-64 at the design sites are given in Table 22.

Monthly flow distribution of the rivers under consideration was determined for the average and low-water years by the models of the real years whose values of the flow rate are close to the design ones and shown in table 23.

Maximum discharges They are available for the Nyando river at Ahero for 7 years and for the Sondu river at 1JG1 for 11 years. The maximum observed flood on the Nyando river made up 9000 cusecs or 151 cumecs (May 10, 1954)

and on the Sondu river, 16508 cusecs or 463 cumecs (April 24, 1964)

Because of the short period of observations it was impossible to calculate maximum discharges of various probabilities by usual statistic method. Therefore for the Nyando river basin maximum discharges of 1% probability were accepted viewing the recommendations given in "Extension of Kenya Nile Basin Water Resources, 1960-61" while the transition to other probabilities is made by probability curves.

For the Sondu river maximum discharges have been calculated by the modulus of the maximum flow of the Nyando river at Ahero, the correction was introduced for higher flows in the Sondu river (K=1.07). This coefficient was derived from the relation between mean maximum discharges of the Nyando river at Shero and those of the Sondu river at 1JG1 for the period of parallel observations. Maximum discharges of various probabilities of the Nyando, Ainomotua and Sondu rivers at the design sites are given in Table 24.

Table 24

Rivers and sites	Catchment area, F sq. mls.	0.5%	1%	3%	5%	10%
Nyando R at Koru	530	36400	32000	25000	22000	17800
Nyando R at Awasi	594	40000	35000	17500	24000	20000
Nyando R at Ahero	1054	53900	48000	37500	33200	27500
Ainomotua R at 1GB5	228	26000	22000	15000	12200	8000
Sondu R at 1JG1	1269	69100	61500	18000	42600	35200

Maximum discharges of the streams in the Kano Plain are determined by the modulus of the maximum flow of the Kibos river at 1HA4 with due regard for the daily maximum of the rainfall. Maximum discharges of the Kibos and Luanda and Oruba rivers are given in table 25.

Table 25

Rivers, sites	Catchment area F, sq. miles	Q_{cusecs} of various probabilities 5%	10%
Kibos R at 2HA4	40	9000	7500
Luanda R at railway site	26.5	5970	4970
Oruba R at railway site	15.0	3380	2820

Flood hydrographs:

For the site at Awasi on the Nyando river and for 1GB5 on the Ainomotua river flood hydrographs of 0.5% and 3% probabilities have been plotted.

The shape of the hydrographs is accepted by the flood models of two real years characterized by the maximum flow volume during the flood period or by the sharpest line of the flood rise. As for the Nyando river the floods of 1955 and 1961 have been accepted as the models of the design floods, while for the Ainomotua river the model is plotted by the floods of 1957 and 1961. The flood hydrographs of design probabilities of the Ainomotua river at 1GB5 and the Nyando river at Awasi are shown in sheet No. 1

Minimum discharges of the rivers under consideration are observed during the dry period from January to March. Table 26 shows minimum monthly discharges of design probabilities calculated statistically for the Sondu river at 1JG1 during the 16 year observation period 1948-63 and for the Nyando river at Ahero (1GD1) during the 12 year observation period 1948-60.

Table 26

(cusecs)

Rivers	$Q_{Mean\ min.}$	Coefficient of variation C_v	Probability	
			75%	90%
Sondu river	264.8	0.76	118	62
Nyando river	78.2	0.53	49	42

Sediment runoff has been calculated for the Nyando river at Ahero with the use of 52 measured discharges of sediment load during five years (1948-49, 1951-54)

The relation between the sediment load and water discharges is shown in sheet no. 1

The given relation permitted to calculate mean monthly sediment load discharges on the basis of 13 year (1948-60) observations over water discharges.

Mean annual water turbidity of the Nyando river at Ahero calculated during 13 years and reduced to 33 year period makes up 2.32 kg/cu.m according to the water flow. Judging by the data of the British firm mean annual turbidity is 2.76 kg/cu.m, i.e. the values are similar. As for the Sondu river the observations over sediment load were not made.

Chemical composition of water. Table 27 gives chemical analyses of the water of the Nyando, Ainmotua, Sondu rivers and Lake Victoria taken from the report "Kenya Nile Basin Water Resources Survey, 1954-56". The analyses have shown that the water of the rivers and the lake is practically sweet and can be used for irrigation.

CHAPTER VI - ALTERNATIVES OF HEAD WATER SUPPLY

The lands suitable for irrigation in the Nyando basin cover 77770 acres (31478 ha) net; the area under similar lands in the Sondu basin must be smaller.

The lands of the middle and upper parts of the Nyando and Ainomotua catchment areas covering 48130 acres (19478 ha) can be irrigated, provided the flow is regulated. The problem of irrigation of these lands has been considered in the report by Sir Alexander Gibb and Partners: Extension of Kenya Nile Basin Water Resources Survey, 1960-61.

The deltaic part of the Kano Plain below Ahero covering 29640 acres (12000 ha) net is fed from Lake Victoria, the Nyando, Ainomotua rivers, as well as from the Sondu river, through the diversion of its flow to the Kano Plain.

According to the character of the head water supply there have been considered two types of water diversion and two types of irrigation i.e. gravity and pump irrigation. The pump irrigation from Lake Victoria has been considered in chapter VII. Given below are possible alternatives of gravity water supply to the proposed area.

When solving the problem of utilization of the Nyando and Ainmotua flows the designers made an attempt to determine the volume of the flow remained after irrigation of 48130 acres (19478 ha) in the upper reaches.

For this purpose the use was made of the 13 year observatopms (1948-61) over the water discharges at Ahero (table 30). It is conventionally accepted that the entire flow of the Nyando Ainomotua rivers is regulated at Ahero.

The water supply for irrigation of 48130 acres (19478 ha) has been based on the data from "Extension of Kenya Nile Basin Water Resources Survey, 1960-61" (table 28). The water requirements for irrigation of land in the lower part of the Kano Plain have been determined from the calculations given in chapter IV (table 20).

The annual many-year storage capacities of reservoirs have been defined for the 75% and 90% probabilities, the dead storage capacity being 20 th. acre-feet (16.2 mill. cu m.)

Table 29 shows the storage capacities of the reservoir and the volume of the water to be spilled under annual regulation. The Table shows that the spills of 75% and 90% probabilities occur only in some months, they are insignificant and cannot be used for irrigation of the lower areas.

In order to study the possibility of many-year flow regulation a number of alternatives has been computed at Ahero with the use of the method of mathematic statistics under various coefficients of flow regulation (from 0.85 to 0.25). The comparison of the volumes of the regulated flow (permitting to irrigate the lands of the Kano Plain) with the volumes of water supplied to these lands has resulted in the fact that the following five alternatives seem to be most attractive.

Table 31

Alternatives	Probability %	Coefficient of flow regulation	Storage capacity : W th. acre-feet
1	75	0.95	94.37
2	75	0.96	116.84
3	90	0.85	85.08
4	90	0.88	110.25
5	90	0.90	134.81

Table 32 gives the values of spills below Ahero with regard for the irrigation of the upper lands according to four alternatives.

Table 32

Observation years.	Reservoir capacities. thous. acre-feet p = 90%		p = 75%	
	W = 110.25	W=85.08	W=94.37	W=116.84
1	2	3	4	5
1948-49	47.69	103.33	95.81	74.27
1949-50	54.74	88.51	88.54	88.54
1950-51	106.0	18.2	106.89	106.68
1951-52	252.82	225.87	228.31	228.31
1952-53	263.59	303.84	398.94	398.94
1953-54	10.82	25.78	10.27	10.23
1954-55	106.43	50.61	191.38	191.38
1955-56	176.90	143.89	157.81	157.77
1956-57	197.95	197.94	298.03	297.97
1957-58	66.38	202.25	202.28	202.28
1958-59	1.94	137.36	137.37	137.41
1959-60	50.24	49.24	59.27	59.27
1960-61	239.74	242.63	239.50	239.50

The above Table shows that only one year of the 4-year period meets the water requirements of the Kano Plain, the water requirements being 203.84 th. acre-feet (251-54 mill. cu. m.) But even this spill should be regulated as in some months its value does not meet water demands. The above considerations have permitted to come to the conclusion that no water will remain for irrigating the lower lands in the Kano Plain after irrigation developments in the upper reaches of the Nyando and Ainomotua rivers. If the project of irrigation of the upper lands is not completed and the entire flow of the Nyando and

Ainomotua rivers is used for irrigation of the lower part of the Kano Plain, not all irrigation lands will be supplied with water even in this case. This alternative is not the best one from the point of view of the cost. The tentative cost of two main reservoirs on the Nyando river at Awasi and on the Ainomotua river at Twin Bridges approximates 122 mill. Sh.

If the regulation is not provided about 5200 acres (2000 ha) may be irrigated from the Nyando river at 75% probability and 3600 acres (1445 ha) at 90% probability (Table 33)

Table 33

Irrigation from Non-regulated Nyando Flow

(Th. acre-feet)

Item	Months												Irrigation area	
	Mar	Apr	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Jan.	Feb.	ha	acres
Nyando flow 75% prpbability.	10.2	24.3	37.6	9.85	7.80	12.4	26.4	18.0	26.4	11.4	5.82	3.80	-	
Water supply	3.0	2.35	2.43	3.51	3.63	3.39	3.92	4.11	3.76	2.91	4.23	3.80	2090	5160
Nyando flow, 90% probability	6.58	6.67	25.8	6.76	5.34	8.46	18.1	12.37	18.1	7.80	3.98	3.64	-	
Water supply	2.3	1.62	1.67	2.43	2.52	2.34	2.71	2.81	2.58	2.71	2.93	2.64	1445	3570

Table 34

Irrigation from Non-regulated Sondu Flow

(Th. acre-feet)

Item	Months												Area	
	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Jan.	Feb.	ha.	acres
Sondu flow, 75% probability	1.75	9.75	18.2	30.8	35.8	80.2	121.9	50.8	26.1	23.7	10.5	10.5	-	
Water supply	1.75	1.33	1.38	1.98	2.07	1.97	2.28	2.39	2.17	2.26	2.40	2.17	907	2240
Sondu flow, 90% probability	1.16	6.44	11.9	20.2	23.6	52.7	80.0	33.4	17.2	15.6	6.9	6.9	-	
Water supply	1.16	0.97	0.98	1.47	1.52	1.41	1.63	1.71	1.55	1.65	1.76	1.59	660	1630

The second reliable irrigation source is the Sondu river. To utilize the Sondu flow it is necessary to divert it to the head diversion site in the Kano Plain. For this purpose it is proposed to design a tunnel 600 m long and 3 m in dia. connecting the Sondu channel with the Asawa channel. From the tunnel the water runs through the Assawa channel as far as the contour 4000 feet. then through the approach channel 25 km long and enters the main canal. Not more than 2240 acres (900 ha.) of sugar land can be irrigated without the Sondu flow regulation (table 34).

Table 35 gives the required storage capacity of the reservoir under the annual regulation of the Sondu flow of 75% and 90% probability. The dead storage capacity equals 1 th. acre-feet (1.2 mill. cu. m.) provided the reservoir is silted. Thus to irrigate the lower part of the Kano Plain, the water consumption totalling 203.2 th. acre-feet (250.75 mill. cu. m) provision should be made for the construction of a reservoir on the Sondu river. Its full storage capacity is 68.8 th. acre-feet (84.9 mi.. cu. m.) ay 75% probability and 103.93 th. acre-feet (128.25 mill. cu. m.) at 90. probability. We are not aware of the information that would permit us to judge the possibility of the creation of such storage on the Sondu river. In the opinion of the Soviet experts who visited the place the creation of such a reservoir is possible 6-7 miles far from the Sondu village upstream the river.

This alternative of water diversion from the Sondu river completely meets the water requirements of the lower part of the Kano Plain. This alternative is not economically attractive as it costs about 200 mill. shillings. It should be noted that the cost should be regarded as tentative and it is to be specified.

Taking into consideration the fact that the cost of the reservoir construction is considerable as well as the fact that the lands in the lower part of the Kano Plain are more fertile, than those of the middle and upper parts of the Nyando and Ainomotua basin it would be rea sonable to start irrigation developments on these lands covering the entire Plain. Viewing this there has been considered the alternative of the use of the flow of both the Nyando and Sondu rivers without regulation. Certain lands should be irrigated by the drainage pumping stations located on the shore of Lake Victoria. This alternative permits to reduce the expenditures meant for diversion and approach facilities to be erected on the Nyando and Sondu rivers to 39 mill. shillings, to establish the priority of construction and land development.

Additional expenditures on drainage-irrigation pumping stations are low, as the complete use of power is made of only drainage pumping stations which work not more than 2-3 months a year.

With the development of irrigation in the upper and middle parts of the basin the lands in the Kano Plain may be irrigated from the same sources that are given for the above alternative with the exception of the Nyando flow which is regulated. The regulated flow remained after the irrigation of the upper lands feed the Sondu flow and the discharge delivered by the drainage-irrigation pumping stations

It should be noted that the irrigation area of the upper lands may be extended making 37640 acres (15 th. ha.) net. Water amounts supplied for the irrigation of the Kano Plain viewing the irrigation sources are given in Table 35(a).

If 48130 acres (19478 ha) of the upper lands are completely developed the creation of the reservoir 66.0 th. acre-feet in capacity on the Sondu river will be required and the Kano Plain will be irrigated only by the regulated flow of the Sondu river

Table 35

Reservoir Storage Capacities Under Annual Regulation of Sondu Flow.

(th. acre-feet)

Months	Inflow		Water supplied to 11187 ha.	Evaporation and see pg. losses		Volume of regulated flow		Spill	
	p=90%	p=75%		p=90%	p=75%	p=90%	p=75%	p=90%	p=75%
Mar	1.16	1.75	24.21	0.02	0.03	41.91	25.33	-	-
Apr	6.44	9.75	*18.54 / 9.66	0.13	0.20	20.02	6.68	-	-
May	11.90	18.20	19.55	0.24	0.37	12.13	4.96	-	-
June	20.20	30.80	26.96	0.40	0.62	4.79	8.18	-	-
July	23.60	35.80	27.88	0.47	0.72	0.00	15.38	-	-
Aug	52.70	80.20	13.87	1.06	1.61	37.77	68.78	-	11.32
Sept	80.00	121.90	21.88	1.60	2.44	94.29	68.78	-	97.58
Oct.	33.40	50.80	23.10	0.67	1.02	103.92	68.78	-	26.68
Nov.	17.20	26.10	21.05	0.34	0.52	99.73	68.78	-	4.53
Dec.	15.60	23.70	22.04	0.31	0.47	92.98	68.78	-	1.19
Jan	6.90	10.50	17.52	0.14	0.21	82.22	61.55	-	-
Feb	6.90	10.50	24.02	0.14	0.21	64.98	47.82	-	-

*In numerator - water supplied from April 1 - 15.

In denominator - water supplied from April 16-30.

Table 35A (th. acre-feet)

Item	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Year
Water supplied for irrigation of 27643 acres (11187 ha)	18.20	21.1	14.70	20.27	20.96	10.43	16.45	17.37	15.83	16.57	13.22	18.06	203.26
Non-regulated Sondu flow, p=90%	1.16	6.44	11.9	20.2	23.6	52.7	80.0	33.4	17.2	15.6	6.9	6.9	276.0
Water supplied by drainage irrigation pumping stations	3.70	3.57	2.80	0.07	-	-	-	-	-	0.97	3.70	3.33	18.14
Regulated Nyando flow after irrigation of 15 th. ha. Spill after irrigation of Kano Plain	-	-	-	-	2.64	42.27	63.55	16.03	1.37	-	-	-	125.86

Future agricultural development of the Plain will require the solution of the problem of power resources in the Nyanza province. In this connection the creation of a reservoir on the Sondu river will solve the problem of power and irrigation. The calculations on the use of the Nyando and Sondu flows of 75% and 90% probabilities are given in table 36.

Evaluating the alternatives of the water supply onemay conclude that under gravity water supply the alternative of the use of the Nyando and Sondu flows without regulation is the most reasonable and cheapest one.

Irrigation of lands from the Kibos river is considered in "Extension of Kenya Nile Basin Water Resources Survey, 1960-61" in the present technical and economic considerations it is accepted without change.

It should be noted that the construction of an expensive weir for a very small area irriga ed from the Kibos river is necessary, the development of these lands should be carried out at the final stage.

CHAPTER VII - IRRIGATION AND DRAINAGE SYSTEMS - ALTERNATIVES

The present Technical and Economic Considerations envisage two alternatives of water diversion - pump and gravity water diversion.

In both cases irrigation water is supplied to the area through the network of main canals delivering water to the inner farm network. Both alternatives provide for the surface method of water application. The design discharges of the canals have been determined in conformity with the water consumption of crops (Table 20, chapter IV). The efficiency of the system has been adopted as equalling 0.75.

1. Alternative of Gravity Irrigation

The irrigation water within the proposed area is to be distributed through five main canals. Main canals have been designed in concrete flumes perpendicularly to the contours, the slopes being 0.001 - 0.0015. Distributors have been designed in earth channels along the contours with the minimum slopes. The area served by one distributor is about 1480 acres (600 ha). The layouts of main canals and the irrigation network is shown in sheet No. 2, the scale being 1:50000. The discharges of the main canals, their lengths and the areas under their command are given in Table 37.

Table 37

Canals	Length km	Q design cu-mecs	Q design cu-secs	Irrigation area, net: Sugar land ha.	Sugar land acres	Rice land ha.	Rice land acres	Total ha	Total acres
Left-bank MC	14.5	1.23	44	744	1838	510	1260	1254	3096
MC-I	22.0	2.89	103	2109	5208	911	2251	3020	7459
MC-II	20.7	2.88	103	1138	2811	1241	3066	2379	5877
MC-III	15.1	3.71	132	1700	4200	1450	3583	3150	7783
MC-IV	10.5	1.56	56	44	109	800	1977	844	1086
MC-V	4.4	1.00	36	30	74	510	1260	540	1334
Total	87.2			5765	14238	5422	13397	11187	17635
Kibos R valley				155	385	658	1621	813	1006
Grand total				5920	14623	6080	15018	12000	29641

Under the alternative of gravity diversion of the Nyando and Sondu flows without regulation, some portion of the area will be irrigated by pumping stations. For this purpose drainage-irrigation pumping stations have been proposed. The capacity is determined by the discharges of drainage canals. The flow probability being 75% it is planned to construct four drainage-irrigation pumping stations

(No. 2, 4, 6, 7) The flow probability being 90% pumping station No. 3 is added.

The calculations of water requirements, flow probability and duration of the operation of pumping stations are given in Table 35 (Chapter VI). The main technical and economic data as well as the volumes of works are given in Sheet No. 2 and 3.

As it has been mentioned above, about 2006 acres (813 ha) of lands are irrigated from the Kibos river. The irrigation of these lands for the particular alternative is taken from "Kenya Nile Basin Water Resources Survey, 1954-56".

2. Alternative of Pump Irrigation

Under the alternative of pump irrigation 23550 acres (9530 ha) of the total area of 29640 acres (12000 ha) are irrigated by water pumped from Lake Victoria, 5234 acres (2120 ha) are irrigated by drainage irrigation pumping stations and 854 acres (350 ha) are irrigated by gravity from the Kibos river.

Three sub-alternatives of water supply to the area have been considered. It is common for all sub-alternatives that water is taken from Lake Victoria at the maximum elevation of 3724.3 feet and the minimum elevation of 3718.5 feet. Under the first (A) and the second (B) sub-alternatives the total water lift is 95.7 feet (31.4 m) to the maximum elevation of 3820 feet. Under the third sub-alternative (C) the water lift is 93.7 feet (30.7 m)

Sub-alternative I(A) - Four zones of water lift have been planned. Pumping station No. 1 located on the shore of Lake Victoria will divert water required for irrigation of the entire area through two pipelines. Through the first pipeline the water will be delivered to MC-I to irrigate the first zone. Through the second pipeline water is to be diverted by pumping station No. 2 and 3 for the irrigation of three zones. Pumping station No.2 supplies water for the irrigation of the second and third zones and for pumping station No. 3. Pumping station No. 3 located at the tenty km of MC-III delivers water to the fourth zone of irrigation.

Sub-alternative II(B) - has also four zones of water lift. Pumping station No. 4 differs from pumping station No. 1 only by its design, its location is just the same. It delivers water to four irrigation zones through one pipeline to MC. From MC some portion of water is diverted by gravity to MC-I for the first irrigation zone, the rest water is diverted by pumping station No. 5 to pumping station No. 6 located at the head of MC-II. Water delivery to the fourth zone of irrigation is similar to sub-alternative I(A).

In accordance with the layout of the irrigation network the area under pump irrigation is divided into the following irrigation zones:

Table 38

Irrigation zones	Canals	Irrigation area net		Including: Rice land		Sugar land	
		ha.	acres	ha	acres	ha	acres
1	MC-I	2520	6227	540	1334	1980	4893
2	MC-II	2800	6919	720	1779	2080	5140
3	MC-III	2720	6721	1860	4596	860	2125
4	MC-III-1	1490	3682	490	1211	1000	2471
	Total	9530	23549	3610	8920	5920	14629

Sub-alternative III(C) - envisages three zones of water lift. Through one pipeline water will be diverted from Lake Victoria to pumping station No. 2 From pumping station No. 2 water will be delivered by gravity to MC-IV. Some portion of water is lifted by pumping stations No. 2 and 8 to the elevation of 3805 feet for MC-V.

Pumping station No. 9 located at the 15th km of MC-V supplies water to MC-V-1.

The layout of the areas under pump irrigation for sub-alternative III is given below:

Table 39

Irrigation zone	Canals	Irrigation area net		Including - Rice land		Sugar land	
		ha	acres	ha	acres	ha	acres
1	MC-IV	5320	13145	1250	3089	4070	10057
2	MC-V	3440	8500	2310	5708	1130	2793
3	MC-V-1	770	1904	50	123	720	1779
	Total	9530	23549	3610	8920	5920	14629

The scheme of water supply according to various alternatives is given in Sheet No. 3, the scale being 1:50000

The irrigation area is 5230 acres (2120 ha). It stretches along the shore of Lake Victoria and is irrigated by means of 7 drainage-irrigation pumping stations.

The analysis of the technical and economic data (Table 40) of all sub-alternatives of pumping irrigation has permitted to accepted Subalternative I which suggests:

1. Minimum number of pumping stations.
2. Most attractive design of pumping stations of chamber and water supply types as compared with pumping stations of block type given in Subalternatives II (B) and III(C)
3. Lesser expenditure on construction.

The above subalternatives have been considered with respect to the conditions of pumping stations operation during 24 hours and with respect to the conditions of water regulation at night storage reservoirs with the total storage capacity of 570 th. cu. m. on all zonal canals.

The comparison of the technical and economic data and expenditures make it possible to conclude thatthe accumulating storage reservoirs are not efficient 'Table 40). Pumping stations are to be supplied with power from high-voltage (66 kv) line coming to Kisumu from Uganda.

The main technical and economic data for the pumping stations of the considered subalternatives and for the drainage-irrigation pumping stations located on the Lake shore are shown in Tables 44 and 45. The technical and economic data for the recommended scheme of pump irrigation are shown in Table 41.

3. Drainage and Escape Network

The soils of the area under consideration are non-saline as a rule, and do not require periodic leachings. Ground water is practically sweet. The construction of levees along the river channels and Lake Victoria prevents the inflow to the irrigation area of the flood water and of the water coming from the highlands. Under these conditions provision should be made for the construction of the drainage-escape network to timely remove the storm and escape waters and prevent bogging.

From the greater part of the area the removal of the storm water is planned by gravity. That is why the Ombei and Miriu channels are straightened, deepened and used as collectors. Besides, three collectors are proposed, their layout is shown in sheets No. 2 and 3. From the leveed area located in the immediate vicinity of Lake Victoria water can be removed by means of pumping stations only. The maximum storm runoff rate of 10% probability for the given area has been accepted as equalling 3 1/sec per ha. The design parameters of the drainage network and pumping stations are shown in tables 42 and 43.

To remove excessive water from the fields provision should be made for the construction of a network of small canals (1 - 1.2 m. deep) the space between canals being 200 m. One of the measures to improve the soils is ridge or bed cultivation. According to this method deep furrows between the ridges are used both as irrigation furrows and as channels through which water is removed. The same drainage network functions to remove excessive irrigation water.

The technical and economic data on the drainage-escape network are given in sheet No. 2

Table 43
Design Parameters of Drainage Pumping Stations

No. of pumping station	Reclaimed area ha. (acres)	Max. discharge cumecs (cusecs)	Max. head geodetic m. (feet)	Design capacity kw
1	660 (1630)	2.0 (71)	1.8 (6)	100
2	420 (1040)	1.3 (46)	1.8 (6)	75
3	450 (1120)	1.3 (46)	1.8 (6)	75
4	410 (1020)	1.3 (46)	1.8 (6)	75
5	190 (470)	0.5 (18)	1.8 (6)	25
6	430 (1060)	1.3 (46)	1.8 (6)	75
7	160 (400)	0.5 (18)	1.8 (6)	25

CHAPTER VIII - FLOOD CONTROL

In the Kano Plain considerable areas are annually innundated by the water of rivers and Lake Victoria. The main rivers of the Kano Plain are the Kibos, Luanda and Nyando. Within the Kano Plain the river gradients are insignificant, their channels greatly meandering. During the seasonal floods these rivers overflow the banks and inundate the adjacent areas. The rise of water in their lower reaches and therefore the floods in the Kano Plain are disastrous. Seasonal fluctuations of water levels in Lake Victoria equal 65 cm many-year range of water level fluctuations is 1.5 m, the maximum range being 1.8 m.

Conventionally the inundation boundary may be accepted along the Nyando River, two miles north of Ahero. The boundary runs along the shore of Lake Victoria and along the Kibos river as far as the point of its confluence with the Awach river (sheet No. 1).

The agricultural development of the Kano Plain is impossible without flood control measures. One of such measures is the discharging of flood flows through straightened, deepened and leveed channels. Besides, there has been considered the possibility of flood reduction by the reservoirs on the Nyando and Ainomotua rivers. Flow regulation of the Kibos and Luanda rivers is impossible.

The design probability of maximum discharges and flood volumes has been adopted as 10% and 5% for leveed channels, 3% and 0.5% provided floods are regulated.

As the morphologic characteristics of the river channels and the data on river cross sections are not sufficient it would be difficult to control floods.

The straightening and deepening (to 6m) of the Nyando, Kibos and Luanda river channels (without levees and with partial levee construction) is not acceptable because of the inadmissible current velocity in the straightened channels (to 4 - 5 m/sec) and big volumes of work. On the Nyando river the volume of work involved in the channel straightening and deepening would make up 1.35 mill. cu. m. On the Luanda and Kibos rivers this volume amounts to 1.13 mill. cu. m. and 1.20 mi.. cu. m. correspondingly.

It has been found that it is impossible to regulate floods because of the lack of the required storage capacities.

Table 46 shows the design flood volumes and maximum storage capacities of reservoirs.

Table 46

Flood Volumes and Maximum Storage Capacities of Reservoirs

(th. acre-feet)

Rivers	Flood Volume p=0.5%	Flood Volume p=3.0%	Reservoirs	Reservoir storage capacity: Acc. to topographic conditions.	Reservoir storage capacity: Required for irrigation	Regulated Flood Volume
Ainomotua	1195.0	666.0	Twin Bridges	60.0	17.9	42.1
			Tinderet	25.0	14.6	10.4
Nyando	1765	1206	Awasi	50.0	19.6	30.4
			Koru	40.0	22.6	17.4
			Londiani	12.0	6.3	5.7
Total				187.0	81.0	106.0

When using the maximum possible (according to the topography storage capacities of the reservoirs on the Ainomotua and Nyando rivers, only 106 th. acre-feet (130.8 mill cu m) may be stored. The rest flow should be spilled through the Nyando river.

The discharge capacity of the Nyando channel below Ahero is 3200 cumecs (90 cumecs) in terms of the flow-284 mill cu m or 230 th. acre-feet.

Under these conditions the following scheme of flood control has been proposed. It is planned to construct levees along the shore of the Kavirondo Gulf, the total length of levees being 52 km. The Nyando and Kibos rivers are to be leveed from both sides. The length of the levees on both sides is 18 km and 12.3 km. It is planned to levee the left bank of the Luanda river, the length of the levee being 18.4 km. The levee intercepts the flows of the Miriu and Ombei rivers and the water is spilled to Lake Victoria. Further on the Luanda river is leveed from both sides. Table 47 gives the design flood discharges of the rivers, main parameters of levees, volumes of earthwork involved in the levee construction and costs.

CHAPTER IX - PROPOSED COST OF DEVELOPMENTS ACCORDING TO ALTERNATIVES AND PRIORITY OF CONSTRUCTION

The cost of the irrigation developments in the Kano Plain has been estimated in the Kenyan shillings for the alternatives of gravity and pump water diversion.

The estimated costs of individual projects have been defined by converting the Soviet prices into the Kenyan currency. The coefficient of conversion k=9.18 has been accepted by the analogy with the approved Project Report on Irrigation of Lnads Under the Cotton and Oil crops State Farms in the Republic of Somalia 1964.

When estimating the costs of the main production facilities the use has been made of the following: "Kenya Nile Basin Water Resources Survey, 1954-56" (report by Sir Alexander Gibb and Partners) "Project Report on Irrigation of Lnads under the Cotton and Oil Crops State Farms in the Republic of Somali, 1964" unit costs and estimates of the Soviet projects.

Other works and expenditures (preparatory works, design and investigation works unforeseen expenditures etc) have been accepted as 23% of the estimated cost of the main production facilities by the analogy with the "Project Report on Irrigation of Lands under the Cotton and Oil Crops State Farms in the Republic of Somalia".

The proposed estimated costs under both main alternatives are given in Table 48.

The maintenance expenditures have been estimated as 4% of the total construction cost by the analogy with the Soviet project reports. Maintenance expenditures pertaining to pumping stations have been based on the water consumption graph.

2. Comparison of Alternatives

As it is seen from Table 48 the total cost of the alternative of gravity irrigation makes up 237.6 mill. shillings while the cost of the alternative of pump irrigation is 157.4 mill. shillings. Annual maintenance expenditures are equal to 10.5 mill.shillings and 13.8 million shillings. Additional capital investments under the alternative of gravity irrigation make up 80.2 million shillings, while the difference in maintenance expenditures is only 3.3 mill Sh

Thus with respect to the economic data the alternative of pump irrigation is the most economically attractice. But pump water diversion will require to solve the power problem as about 6000 kw will be additionally required for the operation of pumping stations. We are not aware at the expense of what sources the power requirements can be met as well as on what conditions and at what price Uganda supplies its power. When making economic calculations the cost of 1 kwh has been tentatively accepted as equalling 0.45 shillings for sunshine hours and 0.08 for night hours. The expenditure on the construction will sharply increase if own power facilities are planned for the provision of pumping stations with power.

Table 48

Expenditures on Irrigation Construction

No.	Structures	Capital investments (Sh.000)	
		Gravity irrigation alt.	Pump irrigation alt.
1	Weir on Nyando river	19330	-
2	Weir on Sondu river	15650	-
3	Weir on Assawa river	9171	-
4.	Sondu feeder canal	8903	-
5	Tunnel connecting Sondu and Assawa channels	5668	-
6	Weir on Kibos river	1320	1320
7	Irrigation pumping stations	-	13311
8	Drainage-irrigation pumping stations	13926	13926
9	Main canals	35597	1274
10	Structures on main canals	3392	7114
11	1st order distributors with structures	2421	13256
12	2nd order distributors with structures	9209	9209
13	Check bunds	3224	3224
14	Collecting-escape network with structures	17886	17886
15	Levelling	28644	28644
16	Roads along main canals	691	647
17	Approach escape canals	345	345
18	Major canals of shore stretches served by drainage-irrigation pumping stations	1598	1598
19	Flood control measures	16179	16179
	Total	193154	127933

Table 48 (contd.)

		Gravity irrigation alt.	Pump irrigation alt.
	Total (b/f)	193154	127933
Incl:	Net-work with Structures	104327	84518
	Headworks	58722	-
	Pumping stations	13926	27237
20	Other works making 23% of the main costs	44426	29425
	Total	237580	157358
	Annual expenditures (maintenance expenditures)	10561	13827
Incl:	Network with structures	4173	3381
	Headworks	2349	-
	Pumping stations	1615	8622
	Flood control measures	647	647
	Other works	1777	1777
	Annual expenditure (maintenance expenditures) per 1 ha. net in $	880	1552

Thus, when comparing the alternatives one should take into account possible capital investments on the creation of own power facilities for the alternative of pump irrigation. In this case the technical and economic data of the latter will be less economically attractive as compared with the alternative of gravity irrigation. The alternative of gravity irrigation permits to more reasonably carry out priority of construction and land development. Therefore, there are some reasons to recommend for further studies (for the preparation of the Project report) the alternative of gravity irrigation with taking of water from the Nyando river, the feeding being carried out from the Sondu river.

Priority of Construction

The priority of construction and agricultural development is defined by the following:

1. Possibility of obtaining maximum income at minimum capital investments per unit of the irrigated area.

2. Necessity of such combination of the construction of the irrigation and drainage systems with the application of flood control measures when the existing reclamation conditions remain unchangeable in the rest, non-developed part of the Plain.

Under the alternative of gravity irrigation the lands located on the right and left banks of the Nyando river and irrigated both by the non-regulated flow of the Nyando river and with the help of pumping stations No. 6 and 7 are to be developed in the first place. Viewing this, the construction of levees on the Nyando river and of the land block drained by pumping stations No. 6 and 7.

The Nyando flow probability being 75% 2090 ha of sugar land can be irrigated. Water consumption of sugar cane and the use of the Nyando flow of 75% probability is shown in table 49. The flow probability being 90% it is possible to irrigate 1445 ha of sugar cane. The water consumption of sugar cane and the use of the Nyando flow of 90% probability are given in Table 50.

Table 49

Water Consumption of Sugar Cane and Use of Nyando Flow of 75% Probability - Area 2090 ha.

Item	Months											
	Mar.	Apr.	May	June	July	Aug	Sept	Oct.	Nov.	Dec.	Jan.	Feb.
1.Ordinate of water duty, 1/ha	0.50	0.40	0.40	0.60	0.60	0.56	0.67	0.68	0.64	0.65	0.70	0.70
2.Water consumption Q cumecs	1.04	0.84	0.84	1.25	1.25	1.17	1.40	1.42	1.34	1.36	1.46	1.46
3.Water supply, Q cumecs	1.38	1.12	1.12	1.67	1.67	1.56	1.87	1.89	1.79	1.34	1.95	1.95
4.Flow, mill.cu.m.	3.70	2.90	3.00	4.33	4.48	4.18	4.84	5.07	4.64	3.59	5.22	4.70
5.Flow, th. acre-feet	3.00	2.35	2.43	3.51	3.63	3.39	3.92	4.11	3.76	2.91	4.23	3.80
6.Nyando flow at Ahero, th.acre-feet	10.20	24.30	37.60	9.85	7.80	12.40	26.40	18.00	26.40	11.40	5.82	3.80
7.Spill after sugar cane irrigation, th.acre-feet	7.20	21.95	35.17	6.34	4.17	9.01	22.48	13.89	22.64	8.49	1.59	-

Table 50

Water Consumption of Sugar Cane and Use of Nyando Flow of 90% Probability. Area 1445 ha.

Item	Months											
	Mar	Apr	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan	Feb
1.Water consumption Q cumecs	0.72	0.58	0.58	0.87	0.87	0.81	0.97	0.98	0.92	0.94	1.01	1.01
2.Water supply, Q cumecs	0.96	0.77	0.77	1.16	1.16	1.08	1.29	1.30	1.23	1.25	1.35	1.35
3.Flow, mill cu.m	2.84	2.00	2.06	3.00	3.11	2.89	3.34	3.48	3.19	3.35	3.62	3.27
4.Flow, ıth acre-ft	2.30	1.62	1.67	2.43	2.52	2.34	2.71	2.81	2.58	2.71	2.93	2.64
5.Nyando flow at Ahero, th.acre-ft	6.58	16.67	25.80	6.76	5.34	8.46	18.10	12.37	18.10	7.80	3.98	2.64
6.Spill after sugar cane irrigation th.acre=feet	4.28	15.05	24.13	4.33	2.82	6.12	15.39	9.56	15.52	5.09	1.05	-

Drainage-irrigation pumping stations No. 6 and 7 may irrigate 1910 ha under rice.

Pumping stations	Q cumecs	Irrigated area ha	acres
No. 6	1.3	1370	3385
No. 7	0.5	540	1334
		1910	4719

The drainage-irrigation pumping stations will operate 2-3 months a year

The use of the Nyando flow of 75% and 90% probability and the operation of the pumping stations are given in Table 51.

At the second stage of development provision should be made for the construction of a tunnel, canal and all structures meant for the diversion of the Sondu flow to the Plain, for the construction of the irrigation-drainage network on the rest of the area and flood control measures.

The tentative cost of construction of the gravity irrigation alternative by stages is given in Table 52.

Table 52

Cost of Gravity irrigation Alternative by Stages

No.	Structures	Construction cost (Sh.000)	Stages I	Stages II
1	Weir on Nyando river	19300	19330	-
2	Weir with tunnels on Sondu River	21318	-	21318
3	Assawa headworks, incl. bank protection works	9171	-	9171
4	Sondu feeder canal	8903	-	8903
5	Weir on Kibos River	1320	-	1320
6	Drainage-irrigation pumping stations	13926	3765	10161
7	Main canals	38989	9589	29400
8	Flood control facilities	16179	3886	12293
9	Major canals of shore stretches served by drainage-irrigation pumping stations	1943	300	1643
10	Roads along main canals	691	187	504
11	Irrigation and collecting-escape networks	61385	19862	41523
	Total	193155	56919	136236
	Other works	44425	13091	31334
	Grand total	237580	70010	167570
	Per 1 Irrigated ha.	19.79	17.50	20.95

As for the alternative of pump irrigation the first stage of construction envisages the water diversion from Lake Victoria to the elevation of 3790 feet for the irrigation of the area of 9884 acres (4000 ha) including 6178 acres (2500 ha) under rice and 3706 acres (1500 ha) under sugar cane.

The boundary of the irrigation areas is the straightened channel of the Ambei River. The following works are proposed:

1. Flood control measures:
 a. Straightening of the Kibos channel and construction of levees along the Kibos river.
 b. Straightening of the Ombei river.
 c. Construction of levees along the Luanda River and on the three stretches of the Lake Victoria shore.
2. Main canal, MC-II and MC-III as far as the Ombei channel and the entire irrigation and collecting-escape network as far as the Ombei channel.
3. Pumping stations - two irrigation pumping stations (No. 1 and 2) and three drainage-irrigation pumping stations(No. 1, 2 and 3)

The second stage of construction envisages to lift water to the elevation of 3820 feet.

Provision should be made for all the rest works:

1. Flood control measures:
 a. Construction of levees along the Nyando river and on the four stretches of the Lake Victoria shore.
 b. Straightening of the Miriu river channel
2. Main canals I and III-1, MC-II and MC-III to their entire length.

3. Pumping stations - one irrigation pumping station (No. 3) and four drainage-irrigation pumping stations No. 4, 5, 6 and 7)

The cost of construction of the pump irrigation alternative by stages is given in Table 53.

Table 53

Cost of Pump Irrigation Alternative by Stages

No.	Structures	Total cost (Sh. 000)	Stages I	Stages II
1	Pumping station No. 1	9089	4850	4239
2	Pumping station No. 2	2753	2753	-
3	Pumping station No. 3	1469	-	1469
4	MC	231	231	-
5	MC-I	2731	-	2731
6	MC-II	2299	1378	921
7	MC-III	2563	1865	698
8	MC-III-1	1212	-	1212
9	Drainage-Irrigation pumping stations	13926	6400	7526
10	Major canals of shore stretches served by drainage-irrigation pumping stations	1598	798	800
11	Approach and escape canals	345	245	100
12	Flood control measures	16179	6750	9429
13	Weir on Kibos river	1320	-	1320
	Total	55715	25270	30445
14	Irrigation and drainage network of 2nd order	72219	10700	51519
	Total	127934	45970	81964
15	Other works	29425	11078	18347
	Grand total	157359	57048	100311
	Per a irrigated ha	13.11	14.25	12.54

CHAPTER X - ECONOMIC FEASIBILITY OF CAPITAL INVESTMENTS

The proposed reclamation of the lands will provide for the increase of yields of crops cultivated on the area of 12 th. ha. The present technical and economic considerations suggest to use these lands for such profitable crops as sugar cane and rice.

At present some part of these lands is used for crop cultivation. The materials available permit to suppose that about 25% of the entire area under consideration is sown.

When calculating the incremented net income it is tentatively assumed that about 10 th. acres (4 th. ha) are under crops, including sorghum about 60%, maize about 20%, cotton about 10%, other crops 10%. The tentative net income from these lands has been estimated at 40.5 Sh per 1 averaged acre (100 Sh per 1 averaged ha). The net income is defined as the difference between the cost of the agricultural production and expenditures. Besides it is necessary to take into account annual maintenance expenditure meant for the irrigation system. The incremented net income represents the difference in the income received after the fulfilment of the project and the income received at present. The cost of the gross production on the lands reclaimed has been estimated at 43090.6 th.Sh, including 30573.3 th Sh

from the sugar land and 12517.3 th. Sh from the rice land.

When estimating the net income it should be taken into account that the major portion of rice production received from the reclaimed lands (about 133 th. quintals or 200 th. quintals of paddy rice) will be exported. The value of one quintal of rice being 80Sh, the cost of the rice production meant for export makes up 10640 th. Sh. Thus the difference between inner and export prices will permit to receive the additional net income equalling 2640 th. Sh.

The total production expenditures have been accepted by the analogy with "Kenya Nile Basin Water Resources Survey" 1954-56, some corrections being added for the difference in yielding capacity adopted in the project report. Production expenditure will be as follows:

Table 54

(Sh)

Plantations	Per 1 acre	Per 1 ha.	Per 1 holding
Sugar cane	388	970	1940
Rice	88	220	352

Note: The area of one holding under sugar cane is 5 acres (2 ha)
The area of one holding under rice is 4 acres (1.6 ha)
The net income received from the reclaimed lands and the incremented net income are tabulated below:

Table 55

(Sh.000)

Plantations	Cost of gross prodn.	General prodn. exp.	Net income	Net income obtained at present	Incremented net income
Sugar cane	30573.3	5895.7	24677.6	197.4	24480.2
Rice	12517.3	1302.8	11214.5	202.6	11011.9
Total	43090.6	7198.5	35892.1	400.0	35492.1

Taking into account the difference between the inner and export prices on rice the incremented net income on the rice land will make up 13651.9 th. Sh, while for the entire area to be improved the incremented net income will be 38132.1 th. Sh. Annual maintenance expenditures allotted to the irrigation system have been estimated at 10561.1 th Sh under the alternative of pump irrigation and 13826.8 th Sh under the alternative of pump irrigation or 356.1 Sh and 466.3 Sh per 1 acre (880.0 Sh and 1152.2 Sh per 1 ha) correspondingly.

The incremented net income for the year of complete development excluding annual maintenance expenditures allotted to the irrigation system is as follows:

Table 56
(th Sh)

No.	Item	Total	Including Sugar land	Including Rice land
1	Incremented net income	35492.1	24480.2	11011.9
2	Do, with regard for export prices on rice 38132	38132.1	24480.2	13651.9
3	Annual maintenance expenditures on irrigation system :			
	a. gravity irrigation	10561.1	5211.9	5349.2
	b. pump irrigation	13826.8	6823.5	7003.3

... cont.

Table 56 (contd)

No.	Item	Total	Including Sugar land	Including Rice land
4	Incremental net income excl. annual maintenance expenditures:			
	a. gravity irrigation	24931.0	19268.3	5662.7
	b. pump irrigation	21665.3	17656.7	4008.6
5.	Do, with regard for export prices on rice:			
	a. gravity irrigation	27571.0	19268.3	8302.7
	b. pump irrigation	24305.3	17656.7	6648.6

The present technical and economic considerations suggest two alternatives of irrigation construction, namely, the alternatives of gravity and pump irrigation. The sum of the capital investments allotted to irrigation construction and to agricultural development adopted when determining the economic feasibility is shown immediately below:

Table 57
(th Sh)

Capital investments	Gravity Irrigation			Pump Irrigation		
		Including			Including	
	Total	Sugar land	Rice land	Total	Sugar land	Rice land
Irrigation construction	237580.0	117317.9	120209.1	157358.5	77741.5	79617.0
Agricultural development	11090.9	5472.5	5618.4	11090.9	5472.5	5618.4
Total	148670.9	122843.4	125827.5	168449.4	83214.0	85235.4

Note: The capital invested in sugar and rice lands has been accepted as tentative proportionately to the areas chosen.

The capital investments falling on 1 acre (1 ha) under reclamation conditions are as follows:

Table 58

Alternatives	Th. Sh per 1 acre (1 ha)		
	Total	Including	
		Irrigation construction	Agricultural development
Gravity irrigation	8.4(20.7)	8.0 (19.8)	0.4 (0.9)
Pump irrigation	5.7(14.0)	5.3 (13.1)	0.4 (0.9)

The main economic elements characterizing the efficiency are: interest on the capital invested and profitableness of agricultural production of the reclaimed lands. The sum making the interest on the capital invested has been defined with respect to the entire sum of the capital investments meant for irrigation construction and agricultural development. The interest has been accepted as equalling 4. The sum taken from the net income as the interest on the capital viewing the alternatives of irrigation construction will be as follows:

Table 59

Alternatives	Total (Sh 000)	Including:	
		Sugar land	Rice land
Gravity irrigation	9946.8	4913.7	5033.1
Pump irrigation	6738.0	3328.6	3409.4

The interest on the capital invested being excluded, the extra profit is as follows:

Table 60 (Sh. 000)

Alternatives	Extra net income Including			Extra net income with re. to exp. prices, Including:		
	Total	Sugar land	Rice land	Total	Sugar land	Rice land
Gravity irrigation	14984.2	143546	629.6	17624.2	14354.6	3269.6
Pump irrigation	14927.3	14328.1	599.2	17567.3	14328.1	3239.2

The profitableness of agricultural development of the reclaimed lands has been defined as the ratio of the profit to the production expenditures. Table 61 shows the profitableness of the agricultural development viewing the alternatives The same Table shows the efficiency.

Table 61

Item	Gravity Irrigation			Pump Irrigation		
	Total	Incl. lands Sugar Cane	Rice	Total	Incl. lands under Sugar Cane	Rice
1. Extra net income, th. Sh	14984.2	14354.6	629.6	14927.3	14329.1	599.2
2. Do, with regard to export prices, th Sh	17624.2	14354.6	3269.6	17567.3	14328.1	3239.2
3. General economic prodn. costs and maintenance exp. th Sh	17759.6	11107.6	6652.0	21025.3	12719.2	8306.1
4. Profitableness (ratio of profit to prodn costs) th.Sh	84.4	129.2	9.5	71.0	112.6	7.2
5. Do, with regard for export prices th Sh	99.2	129.2	49.1	83.6	112.6	39.0
6. Efficiency (ratio of incremented net income to capital investments	0.10	0.16	0.05	0.13	0.21	0.05
7. Do, with regard to export prices	0.11	0.16	0.07	0.14	0.21	0.08

Para 2 of chapter II shows the gross production received by a farmer from his holding and the cost of the produce. In order to determine the net income from one holding, general economic production costs and maintenance expenditure are deducted from the cost of gross produce. The net income per 1 holding under the alternatives of the irrigation construction is given below:

Table 62 (Sh)

Crops	Cost of gross yield	General economic prodn costs	Maintenance exp. Gravity irrig.	Maintenance exp. Pump irrig.	Net income Gravity Irrig.	Net income Pump Irrig.
Sugar cane	10325	1940	1760	2304	6625	6081
Rice	3295	352	1408	1843	1535	1100

However, it is necessary to take into consideration that about 85% of the rice cropped is exported. The difference in inner and export prices gives the extra net income approximating 1400 Sh per 1 holding. Thus the net income in rice growing farms is about 2935 Sh under the alternative of gravity irrigation and 2500 Sh under the alternative of pump irrigation.

In order to rise the net income from 1 holding in rice growing farms up to the level of the net income from 1 holding of sugar cane farms one may suggest to enlarge the size of holdings in rice growing farms. But in this case some of the agricultural operations should be mechanized, as the farmer will not be able to till the enlarged holding.

The period of justification has been estimated by the methods used in the USSR. This period with regard for the export prices on rice is as follows:

Gravity irrigation		Pump irrigation	
for the entire area	9 years	for the entire area	7 years
for the usgar land	6-7 years	for the sugar land	5 years
for the rice land	15 years	for the rice land	13 years

CHAPTER XI - PROGRAM OF RECONNAISSANCE SURVEY AND RESEARCH WORK TO BE CARRIED OUT FOR PREPARATION OF PROJECT REPORT ON IRRIGATION OF LANDS IN KANO PLAIN

The preliminary report (the present technical and economic considerations) envisages the irrigation of 12000 ha. net of lands under sugar cane and rice in the Kano Plain.

The present program of reconnaissance survey and research works has been prepared with respect to the recommended alternative of irrigation from the Nyando and Sondu rivers without flow regulation. Some lands are to be irrigated with the help of pumping stations which are located on the shore of Lake Victoria and take water from the Lake.

In conformity with the proposed plan of irrigation development in the Kano Plain the following works are to be fulfilled on the area of about 40000 ha in 1965-66: topographic, engineering-geologic, hydrogeologic, soil-reclamation, hydrologic and agro-economic investigations.

To fulfil the above works in due time an expedition of 48 engineers and technicians should be organized. The need for delegating the Soviet experts will depend on the availability of the Kenya specialists of corresponding qualifications. When considering the list and the number of experts, the period of fulfilment of reconnaissance survey and research works has been accepted as equalling 18 months. The programs of separate kinds of surveys and research works are given below:

Topographic Survey

To provide the project report on irrigation of lands in the lower part of the Kano Plain with topographic data it is necessary to carry out the following topo-geodetic works:

1. Interpretation of the photoplans at a scale of 1:10000 prepared on the basis of the British aerial photographic survey of 1964 on the area of 40000 ha.
2. Topographic survey with the contour intervals of 0.5 m on photoplans at a scale of 1:10000 covering the area of 40000 ha.
 As for the elevations, levelling traverses are to be made 1.5 km per 100 ha of the survey totalling 600 km. When surveying the area all wells, boreholes, structures and other objects are to be shown on the photoplans.
3. Alignment of the main canal from the diversion site on the Assawa river to the irrigation area, 200 m land strip being surveyed. The total length of the canal is 26 km. The area is surveyed at a scale of 1:10000 with the contour intervals of 1.0m.

4. Plane-table survey of the sites at a scale of 1:1000 with contour intervals of 0.5m.

Concrete weir on the Sondu river	25 ha
Concrete weir on the Assawa river	10 ha
Concrete weir on the Nyando river	10 ha
Total	45 ha

5. Plane-table survey of the inlet and outlet parts of the tunnel on the Sondu-Nyando canal at a scale of 1:500 with the contour intervals of 0.5 m. The area to be surveyed is 10 ha.

6. Alignment of the tunnel 600 m long on the Sondu-Nyando canal. For the preparation of the plans for designing and construction of the tunnel the network of the IIIrd-order triangulation will be laid from six points. To show elevations the IVth-order levelling is performed at the distance of 3 km.

7. Plane-table survey at a scale of 1:1000 with contour intervals of 0.25 m of seven pumping station sites. The area to be surveyed is 28 ha. The survey points are determined by theodolite-levelling traverses. One ground bench mark is to be installed at each site.

8. Alignment of approach channels from Lake Victoria to the hydropower station, the length being 7 km. On the routes of the approach channels and at typical places cross lines are laid spaced at 100-200 m.

9. Measurement of the Lake Victoria depth, 3 sites being at each diversion.

10 Tieing of geologic prospect points in plan and elevations, the total of 700 points.

All topographic works will be performed in the systems of coordinates and elevations adopted when preparing photoplans at a scale of 1:10000.

After the fulfilment of the works the following data will be presented:

1. Plans and their copies of surveys of all scales.

2. Longitudinal profiles of: main canals, take-off canals, the Sondu river at a scale of 1:10000, routes of water supply to pumping stations and cross lines through Lake Victoria at a scale of 1:1000. The vertical scale for all profiles is 1:100.

3. Profiles of cross lines at a scale of 1:100.

4. Plan at a scale of 1:10000 showing alignments and geologic prospect points.

5. List of coordinates and elevations of alignments, geodetic points and geologic prospect points.

6. Technical report on the fulfilled work prepared in Russian and English.

Maps will be prepared and printed in the USSR.

Engineering-Geologic and Hydrogeologic Investigations

The following kinds and volumes of hydrogeologic and engineering-geologic works have been proposed:

A. Irrigation Area and Canals

1. The area under the proposed irrigation should be hydro-geologically surveyed at a scale of 1:50000. The area to be surveyed covers 400 sq. km (40000 ha). The geologic map of this area at a scale of 1:50000 is not available.

2. The hydrogeologic survey at a scale of 1:50000 should be based on the information obtained as a result of drilling of 200 boreholes of which:

a. Five boreholes are to be drilled to the average depth of 200 m. These boreholes should be regarded as basic ones and will be located at two sites. One of the sites will

will be longitudinal (in respect to the Plain) and the other one transversal. Within the thickness bands of coarse rock debris may be expected as the source area is rather close. Therefore, these boreholes should be sunk by the method of cable or combination drilling with casing

b. The valleys of numerous rivers that cross the Kano Plain are often bogged. At such places 50 boreholes are proposed. These boreholes will be drilled by hand rotary method to the depth of 15 m.

c. To determine seepage properties of the rocks composing the area under consideration 8 test groups of boreholes are proposed, each consisting of a principal borehole and two observation boreholes. When drilling these boreholes it is necessary to accurately record the aquifers met. Hence all test boreholes should be drilled by the core method (with casing) without flushing. The depth of boreholes is 20 m. For the rocks of the aeration zone it is planned to dig 25 pits (for pouring-in) about 5 m deep.

d. To study the ground water regime 20 observation boreholes are to be sunk by the method of core drilling with casing, the average depth being 15 m.

e. Eighty boreholes are to be drilled on the remaining area. The boreholes are to be sunk by the method of core drilling with casing, the average depth being 10 m.

3. One hundred boreholes are to be drilled to study the geologic structure and lithologic cross section along the routes of the proposed canals about 200 km in the total length. These boreholes will be sunk by the method of core drilling with casing, the depth being 5 m.

4. To take monoliths and to study seepage properties of the rocks occurring along the routes of the proposed canals 40 pits 2.0 sq. m in cross section and 20 pits 2.5 sq m. in cross section are proposed, the depth being 5 m.

5. To study deep interstratum aquifers and the possibilities of their utilization for water supply 5 test pumpings-out from deep boreholes are proposed, the water is to be pumped from the depth of about 60 m. Water will be pumped at three drawdowns, the minimum one should not be less than 1 m. The duration of the pumping-out per one drawdown is 3 days.

6. To obtain the data required for the preparation of the ground water balance and for the forecasting of the ground water table changes the following works are proposed: test pumpings-out from group boreholes, test pourings-in to single pits and observations over the ground water regime at the observation boreholes. The total of eight group pumpings-out are planned for the proposed area. Each group consists of a principal borehole and two observation boreholes located in the direction of the ground water flow. The spacing between an observation borehole and the principal one is to be chosen on the spot depending on the lithologic composition of water-bearing rocks.

The screen diameter of principal boreholes is 168 mm, while that of observation ones - 89 mm, the length of the operation part of the screen is 10 m. The pumping-out at each group is performed at three drawdowns in 12 shifts.

Twenty-five pourings-in by Nesterov's method of pits are proposed in the rocks of the aeration zone, the duration of each pouring-in being 9 shifts. For this purpose 25 pits 2.5 sq. m in cross section and 5 m deep are planned.

The ground water regime should be studied at 20 observation boreholes 15 m deep. The screen diameter of these boreholes is 89 m, the length of the operation part of the screen being 10 m.

Observations will be carried out during the entire hydrologic year. Water levels in boreholes will be recorded three times a month.

The observation boreholes will be located at two regime cross lines. At the points where the cross lines meet surface water streams staff gauges are established on these streams. At the staff gauges and observation boreholes water is sampled and levels are recorded.

Bailing 1-2 hours long with further recovery of the water level will be carried out at all principal and observation boreholes after screen installation.

One-litre water samples for the reduced chemical analysis will be taken from the principal boreholes for each drawdown at the end of the pumping out.

From the boreholes meant for the observations over the ground water regime water will be sampled each month for the reduced chemical analysis.

7. To define physical and technical properties of the soils it is proposed to take 25 monoliths from the boreholes and 30 monoliths from the pits.

8. One hundred and forty boreholes and sixty pits are proposed along the routes of canals and levees. Forty of these boreholes are required for the hydrogeologic survey of the area.

Boreholes and pits are spaced at 1 km. The depth of boreholes and pits is 5 m. Thus, the total length of boreholes and pits sunk along the routes of canals and levees will be 500 m. Test pourings-in by Nesterov's method are planned at 20 pits, the duration of each test being 9 shifts.

To define physical and technical properties of soils 40 monoliths 20 x 20 x 20 cm in size should be taken from hard rocks. The monoliths and samples taken will permit to define the following soil properties: texture, plasticity limits, molecular moisture capacity, natural humidity, density, specific weight, share strength, compression strength.

B. Hydraulic Structures

To partially divert the Sondu and Assawa flows to the Nyando river provision should be made for the construction on these rivers of the weirs 10 m high and of the tunnel 600 m long.

1. To study the geologic structure and engineering-geologic conditions for the construction of weirs the engineering-geologic survey at a scale of 1:2000 on the area of 2.5 sq. km. is planned. For this survey 27 boreholes each 20 m deep will be sunk at the sites and axes of the proposed weirs. Of this number six boreholes are planned along the axis of the weir on the Sondu river, the length of drilling totalling 120 m.

On the Assawa river there will be drilled three boreholes with the total length of 60 m.

On the Nyando river three boreholes are proposed with a total length of 60 m.

To better understand seepage properties of the soils occurring at the sites of the proposed weirs it is planned to carry out one group pumping-out at each site. The test group is composed of a principal borehole and two observation boreholes each 200 m. deep. The screen diameter boreholes is 89 mm. The length of the operation part of the screen is 10 m. Pumping out should be performed at three drawdowns. The duration of the pumping out at one drawdown is four shifts.

In addition to pumpings-out performed at the weir site on the Sondu river water injections are planned for two boreholes at four intervals, one interval equalling 5 m. To define the physical and technical properties of the soils 9 monoliths should be taken from the boreholes.

2. Along the tunnel route three boreholes should be sunk by the method of core drilling, each being 30 m deep. The total length sunk is 90 m.

To evaluate the degree of jointing of crystalline rocks occurring at the tunnel site injection to one borehole at six intervals is planned, one interval equalling 5 m. From the boreholes on the tunnel route three monoliths will be taken.

3. The engineering-geologic survey at a scale of 1:10000 is planned for the strip 1 km wide along the route of the main canal, the length of the latter being 26 km.

For the above survey 45 boreholes should be drilled including 15 boreholes along the canal route, the depth being 6 m. The total length is 270 m. For the same reason 45 pits are proposed 5 m deep. 23 pits are 2.0 sq m in cross section and 22 pits are 2.5 sq. m in cross section. The total length is 225 m.

To better understand the seepage properties of the rocks occurring along the canal route there are planned 10 test pourings-in to the pits by Nesterov's method, the duration of each test being 9 shifts. Six monoliths are taken from the boreholes and ten monoliths are taken from the pits.

4. To study the geologic-lithologic cross sections of the sites of 7 proposed pumping stations provision should be made for the drilling of 21 boreholes, each being 15 m deep. They are to be sunk by the method of core drilling. The total length is 315 m.

Fourteen boreholes are proposed for the stretches from the water diversion sites to the shore of Lake Victoria (for all 7 pumping stations). These boreholes are to be sunk by the method of percussion-rotary drilling from rafts, the water level fluctuations in the Lake being 1 m, the depth 15m. The total length is 210 m.

To study the physical and technical properties of the soils 84 monoliths should be taken from the boreholes at the sites of pumping stations and along the water supply routes. These monoliths are required to fulfil all kinds of investigations.

5. The geologic survey is planned for the length of 1000 km to search for local construction materials. For the purpose of prospecting the deposits of construction materials discovered it is planned to drill 8 boreholes to a depth of 15 m each. The method of core drilling was applied. The total length is 120 m. Besides, 12 boreholes each 7 m deep are proposed, the total being 84 m. Thirty pits should be dug strengthening being provided. Each pit is 5 m deep.

Ten lump samples are taken from the stone deposit 25 x 25 x 40 cm in size. The following physical and technical properties of the samples selected are determined at the laboratory:

- organic impurities
- granulometric composition
- density
- specific weight
- content of mica
- composition of sulphuric and sulphurous compounds
- compression strength
- wear test in Duval's cylinder
- petrographic analysis

6. The results of the investigations should be given in the report, tables and graphs are to be appended .

Soil Survey

Provision should be made for general reconnaissance survey to prepare the soil classification as well as for the future soil survey at a scale of 1:25000 permitting to distinguish the boundaries of soil varieties, degree of salinization, salt composition and soil texture.

In order to prove and verify the field data of the soil survey made for the entire area the following laboratory works are planned:

1. Determination of the bulk composition by the method of Guedroitz, determination of salt-acid extract and of the bulk gypsum.

2. Analyses (50% of all samples) of the reduced water extract to determine the nature and degree of salinization.

3. Determination of the granulometric composition (pipette method) to verify the lithological differences.

As the test data pertaining to the water and physical properties are not available there arises the necessity to carry out investigations at 20 experimental grounds, the land levelling is required. The determination of the furrow lengths is very important. In this connection two additional water and physical points should be provided.

Two experimental points for studying the values of leaching rates and salt yield should be established on saline soil varieties. Leaching should be carried out at a rate of 3-6-9-15-20 th. cu.m per ha.

As the irrigation requirements for different crops are unknown observations over the dynamics of water with respect to the vegetation phases are necessary.

It is planned to study the existing irrigation rates under the natural conditions, to study the wet perimeter of furrows, velocity of the water stream in furrows and furrow lengths, spacing between them, length of the inter-irrigation period, soil humidity prior to and after irrigations, depths of soil wetting when irrigating.

Soil surveys will allow to prepare:

1. Soil report
2. Soil-reclamation map, scale 1:25000

Hydrologic Works

According to the present program there will be carried out field and design hydrologic works on the rivers crossing the Kano Plain, on the Sondu river and on Lake Victoria, with due regard for the existing discharge stations in Kenya.

A. Hydrologic works on rivers

The following kinds of work are to be carried out: reconnaissance survey of the river basins, establishment of staff gauges and recording during one year, water sampling and fulfilment of chemical bacteriological and mechanical laboratory analyses of suspended load, level measurements and collection of hydrologic and meteorologic observation data for previous years.

The main purpose of the reconnaissance survey of the basins of big rivers (Sondu, Nyando Ainomotua) on the stretch of 100 km is to characterize the physiography of the lower part of the river basins, to find the maximum water levels in the rivers and the inundation zones.

The reconnaissance survey of the basins of smaller rivers and water streams crossed by the proposed main and zonal canals or cut by levees is aimed at the obtaining of the data required for the calculation of maximum discharges of these streams. The stretch to be surveyed is 100 km long.

The survey of cross lines of river and water stream valleys as far as non-flooded elevations at the sitrd of the existing and proposed staff gauges and discharge stations as well as the survey of gradients of the rivers and water streams on the stretch of 50 km.

In addition to the existing hydrometric network provision should be made for the establishment of five main and 12 temporary staff gauges and two discharge stations on the Kibos and Oruba rivers equipped with boats.

Five main staff gauges and two discharge stations should be maintained within a year.

The elevations of 20 existing and proposed observation sites should be tied to the basic geodetic network on the stretch of 100 km.

Water sampling and laboratory analyses are proposed in the following volumes: mechanical analyses of suspended particles 20, complete chemical analyses 50, bacteriological analyses 30.

The program envisages the collection of hydrologic and meteorologic data for the many-year period at 14 discharge stations and 8 meteorologic stations (without the additional studies of the materials).

B. Hydrologic Works on Lake Victoria

The reconnaissance survey of the shore of Lake Victoria has been proposed with a view to define the effect of waves on the shore at the sites of the proposed pumping stations as well as the reconnaissance survey with a view to choose one observation site.

To study the levels of Lake Victoria it is proposed to install at the pumping station sites one temporary coastal tide gauge and perform hydrologic observations during one year.

It is planned to carry out short-term observations over silt, deformation of the shore and the bottom. There will be no observations over the velocity and current direction.

The mechanical and petrographic composition of the suspended load will be given on the basis of the analyses to be fulfilled at each observation site. To characterize the physical and chemical properties of the water of the Lake it is proposed to perform four complete chemical and four bacteriological analyses at each observation site. In addition to the above there will be determined aggressive properties of water (also 4 analyses for each observation site). It is planned to collect, classify and to study the observation data of the previous years. It is also planned to collect and to study the data on monthly observations over the wind per 28 years, observations over the waves per five years, observations over water levels per 22 years, 25 chemical analyses of water, number of stormy days per 28 years.

C. Design Hydrologic Works on Rivers

1. Preparation of summary technical report on the works carried out under natural conditions.

2. Additional studies of the hydrologic and meteorologic data collected in recent five years at 14 discharge stations, 2 meteorologic stations and 6 rain gauges.

3. Preparation of the detailed hydrogeologic report on all the rivers flowing through the plain and on the Sondu river with due regard for the total number of observation years at all stations (200) at 23 sites and under various physical and geographic conditions in the river basins.

4. Calculation of maximum water discharges, flood volumes and flood hydrographs of wadis at the places of their crossing with canals - at ten sites.

D. Design Hydrologic Works on Lake Victoria

1. Classification and studying of the observation data of the previous years in the volume given in item 'C'.

2. Determination of silting with the use of the observation data studied.

3. Wave calculations at one observation site.

4. Preparation of separate sections of the hydrologic report:

a. water levels per 22 years,
b. waves per five years,
c. silting per one year,

d. physical and chemical water properties,
e. wind per 28 years.

Agro-Economic Works

The following works are involved in the agro-economic investigations:

1. Reconnaissance survey of the territory 40000 ha in area with the aim to choose the lands under the proposed irrigation.

2. Studying and obtaining of the information on present state and future developments of agriculture in Kenya as well as the export and import of agricultural produce, agricultural population and its occupation.

3. Obtaining of the available mapping data on the area under consideration. Present land resources and their utilization.

4. Present state of agriculture within the irrigation area. Composition of crops, crop rotation, fertilizers, irrigations. Dates of field operations. Farming methods applied and yields, mechanization of agricultural operations.

5. Study of the existing farms with a view to determine the optimum sizes of farms. Types of cooperatives and their future development.

6. Obtaining of the economic data necessary for the Project Report. Sale, conditions, import, export and inner prices of agricultural produce, conditions of transportation, processing and marketing of agricultural produce.

The following problems will be elucidated in the agro-economic section of the project report:

1. Land organization within the irrigation area.

2. Organization of agricultural branches.

3. Measures, volume of works and costs involved in agricultural development of irrigation lands.

4. Economic feasibility of capital investments.

In addition to the above reconnaissance survey and research work there should be carried out the works for the collection of the data required for the preparation of the project of organization and execution of works.

The design works are to be fulfilled in the USSR during 12 months.

The present program takes into account all recommendations of the Kenyan side pertaining to the kinds of investigations proposed in the memorandum of Minister of Agriculture of the Republic of Kenya, Mr. McKenzie. The organization of additional meteorologiv observations suggested in the Kenyan program is not planned as, in our opinion, the existing meteorologic network is sufficient to give the climatic characteristics of the Plain.

As for the organization of the experimental station and plots the Project will suggest the necessary recommendations pertaining to their location and work. The designing of experimental research stations, their equipment and construction these problems should be the subject of the future discussion as it is necessary to study the possibilities of the Kenyan side.